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A Summary of Current Program and
Preliminary Report of Progress

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HORTICULTURAL CROPS RESEARCH

of the

United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

Section B

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D.C.
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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS

Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of food available to consumers change constantly with the adoption of new practices of production, processing, and marketing. Changing constantly also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, on the nutrient and other values of foods, and on ways to conserve or enhance these values in household and institutional preparation and processing.

The kinds and amounts of foods consumed by different individuals and population groups must be determined periodically so that the nutritional adequacy of diets can be evaluated. Information on food consumption and dietary levels provides the guidelines needed for effective consumer nutrition programs. This information also furnishes the basis for market analyses for different commodities and for development and evaluation of agricultural policies and programs that relate to production, distribution, and consumer use of food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of improved procedures for household food preparation, care and preservation; (3) nutritional appraisal of food supplies and diets of different population groups; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service--the Human Nutrition Research Division at Beltsville, Maryland, and the Consumer and Food Economics Research Division at Hyattsville and Beltsville, Maryland and Knoxville, Tennessee. Some of the research in both divisions is done under cooperative, contract, or grant arrangements with State Experiment Stations, universities, medical schools, hospitals, research institutes, and industry. The total Federal scientific effort devoted to research in these areas is 81.7 man-years. It is estimated that 17.0 scientific man-years is concerned with studies related to horticultural products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis,

though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 19.8 scientific man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to vegetables and fruits are considered briefly in this report.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Nutrient and Other Consumer Values of Horticultural Products

1. Mineral elements in fruits. Studies on the individual mineral elements in fresh fruits were completed. Samples of known origin were purchased from the Washington, D.C. market. Production areas extended from New England to California. Ecuador, Honduras, Hawaii were some of the producing areas outside the continental United States. Thirty fresh fruits were analyzed for eleven mineral elements, total ash, and total solids. Sample variation within a producing area was greater than the variation among different producing areas. Manganese and sodium content exhibited the largest area variation, the highest being a 23-fold range (38 to 888 micrograms per 100 grams) for the manganese content of bananas grown in Jamaica and a 12-fold range (3.16 to 36.49 milligrams per 100 grams) for the sodium content of winter varieties of avocados grown in California. Among producing areas, only rhubarb and avocado exhibited differences in total solids, ash, fat (avocado only), and sodium large enough to be nutritionally important. In addition, rhubarb from the various producing areas differed in nitrogen, aluminum, calcium, copper, potassium, and phosphorus. A manuscript reporting these data has been accepted for publication in the American Dietetic Association Journal.

2. Effect of herbicides on quality of fruits and vegetables. A series of studies are being conducted in cooperation with the Crops Research Division on the effects of herbicide soil treatments on fruits and vegetables.

Blueberries and peaches were grown on soil treated with diuron and simazine. Number and rate of applications were plot variables. Blueberries and peaches were evaluated for color, texture, and flavor by panel. Physical measurements of color and shear force were made on peaches but not blueberries.

Red Rome apples were grown in New Jersey in orchards treated with diuron, simazine, CIPC (isopropyl N (chlorophenyl) carbamate) or amitrole and compared with a plastic mulch treatment, a weedy control, and a clean control. Panel evaluations for flavor and texture were made; shear force values were also obtained. Relationships between eating quality and composition will be established.

Carbohydrates were determined in the apples, blueberries, and peaches grown on soils treated with the different herbicides. Analyses were made for total solids, total and reducing sugars, sucrose, glucose, and fructose. In only one case did the herbicide treatment significantly affect sugars. The peaches

grown on soils treated with simazine at 4 pounds per acre were significantly higher than others in sucrose, 6.8 as compared with an average of 6.3 percent. This finding agreed with taste panel results; these peaches scored highest in flavor. Differences between crop years in the amount of sugars in apples and in blueberries were greater than the differences among herbicide treatments.

A manuscript, including the data on total solids and sugar content is in preparation.

The effects of monuron, amiben, diphenamid, simazine or linuron treatments on the palatability of asparagus are being studied also. Panel evaluations of color, flavor, and texture and physical measurements of shear force and color are being made. Trace mineral elements are being determined. This work is in progress.

3. Effect of fumigants and fungicides on quality of vegetables and fruits. Studies were continued on the effects of PCNB (pentachloronitrobenzene) soil treatment on the palatability and composition of potatoes. Off-flavor due to PCNB treatment could be detected by only one of the six judges. This judge consistently identified potatoes grown in PCNB-treated soil and apparently was extremely sensitive to PCNB. Significant chemical changes were observed. Potatoes grown in PCNB-treated soils were lower in tyrosine content than control potatoes. As a result of the lower tyrosine content, enzymic browning was less in potatoes grown in treated soils than in the control potatoes. There were significant changes in organic acids and amino acids during storage. Changes were greater at 70° F. than at 55° F. Citric acid, alanine, isoleucine, phenylalanine, tyrosine, and valine increased. Aspartic and glutamic acids decreased. A manuscript is being prepared, and a paper describing this research will be presented at the American Chemical Society meeting in Chicago, Illinois, September 10-15, 1967.

Under a contract with the University of California at Los Angeles, research on the effect of soil fumigants and fungicides on fruit and vegetable quality has been initiated. A root crop, carrot; a legume, lima bean; a raw salad vegetable, celery; and a fruit, orange, are to be used in the soil fumigation studies. Fungicides will be used on oranges, strawberries, and tomatoes. The choice of fumigants and fungicides is based upon accepted commercial practices. Each fruit and vegetable will be examined fresh and after appropriate home preparation including freezing, cooking, canning, and making jelly. The foods are to be analyzed for selected nutrients, including carbohydrates, nitrogenous substances, vitamins, and minerals, as well as for flavor, color, and texture.

4. Effect of insecticide and fungicide treatments on strawberry quality. Investigations have been completed on the effect of the insecticides demeton and chlordane, and the herbicides captan and ferbam on palatability and composition of strawberries (see 1966 report, p. 216). The treatments had

no detectable effect on color, texture or flavor of strawberries. Head space analysis of strawberry volatiles from control and treated berries gave similar chromatographic patterns. There were highly significant decreases in the malic acid content of Earlidawn and Armore strawberries treated with demeton. The chlordane-treated fruit showed significant malic acid decreases only for the Earlidawn variety. Decreases in malic acid, titratable acidity, and soluble solids, although statistically significant, were too small to be of practical significance. Residue analysis showed that traces of demeton (less than 0.05 ppm) were found on two of seven demeton-treated samples. Chlordane was found in four of seven samples of both control berries and chlordane-treated berries. Because all strawberries were grown on soil that had been treated with chlordane the year prior to these experiments, chlordane carry over in the soil could account for the chlordane residues found in the control berries. A manuscript is being prepared.

5. Insecticide removal from vegetables. Research on the effect of preparation and cooking on the pesticide residues of selected vegetables continued under contract with the National Cannery Association in Washington, D.C., and Berkeley, California. All pesticide treatments and residues were within recommended tolerances.

Tomatoes. Commercial washing operations removed between 83 and 95 percent of malathion residues. Commercial processing and juicing of peeled tomatoes lowered the residue to less than 1 percent of the initial value. During home preparation, a cold water wash was ineffective in removing residual malathion; peeling removed more than 90 percent. Storage of fresh tomatoes for 10 days resulted in a decrease of about 30 percent in the malathion residues.

Spinach. Commercial washing procedures removed only 25 percent of the parathion residue; further processing removed another 40 percent of the initial residue. During home preparation, a cold water wash removed about 39 percent of the initial residue; household blanching and cooking were ineffective in removing parathion. Storage for 12 days at refrigerator temperatures produced no change in residue levels.

Commercial washing operations removed up to 70 percent of DDT residue on spinach depending on the length of the wash; further processing removed approximately 90 percent of the initial DDT residue. During home preparative procedures, washing removed about 30 percent of the DDT residue. After washing, no significant decrease in residue was noted by home cooking; blanching for freezing removed about 53 percent of the initial DDT residue. There was no significant loss of residue during storage at refrigerator temperatures for 15 days.

Almost 90 percent of carbaryl residue on spinach was removed by commercial washing procedures; further processing removed 90 percent of the initial residue. More than 80 percent of the carbaryl residue was removed by home preparative procedures.

Potatoes. Commercial washing removed about 25 percent of DDT residue. Washing plus lye-peeling removed about 85 percent. Commercial processing reduced the residue to insignificant level. During home preparation procedures, peeling removed approximately 95 percent of the DDT. Potatoes boiled and pressure cooked without peeling showed no significant decrease in residue level. Residue levels were unchanged in potatoes stored at 45° F. for 6 weeks.

Manuscripts have been prepared for publication and phases of this research were presented at the American Chemical Society meetings in New York, September 1966, and Miami Beach, Florida, April 1967. Two papers will be presented at the American Chemical Society meeting in Chicago, Illinois, September 1967.

6. Color of fruits and vegetables. A program has been initiated to determine the qualitative and quantitative changes that take place, after harvest, in the pigments of fruits and vegetables. Preliminary studies on blueberries and sour cherries are under way. This kind of information will serve as a guide to the establishment of conditions for the maintenance of color quality in household and institutional food storage and food preparation.

7. Texture of vegetables. Plans have been developed to initiate research on the textural changes that take place during household and institutional storage of selected vegetables. Histological techniques applied to thin tissue slices will play an important role in these studies. Methodology for cryoscopic microtomy of peas has been developed.

B. Tables of Food Composition

1. Amino acids. An extensive search for published and unpublished data on the amino acid content of food is underway. Priority is being given to deriving representative values for amino acids in fruits and vegetables. Preliminary values have been derived for the phenylalanine content of about 15 fruits and 25 vegetables and for the tyrosine content of 10 fruits and 20 vegetables. The values for phenylalanine content are much lower than the widely used values calculated as 5 percent of the protein content of the fruit or vegetable. These lower values indicate that larger quantities of fruits and vegetables than presently allowed can be safely included in the diets of children with phenylketonuria. A journal article is being prepared.

2. Revision of Handbook No. 8. Work to obtain data for the next revision of Agriculture Handbook No. 8 "Composition of Foods...raw, processed, prepared" is proceeding along several lines. A search of the literature for data on the sodium and potassium content of foods has shown that poultry, a number of important fruits including bananas, spices and condiments, and nuts are among the foods for which few data for sodium and

potassium are available. Possible arrangements for obtaining such data are being explored. A source of extensive data on trace elements in foods has been located and tentative arrangements have been made for obtaining the data.

3. Nutritive value of retail and household units of food. The development for publication of a table showing nutritive values of foods in terms of common retail and household units is continuing. Values will be given for proximate composition, calcium, phosphorus, iron, sodium, potassium, vitamin A, thiamine, riboflavin, niacin, ascorbic acid, and selected fatty acids. Final values are ready for more than 500 items of food and are nearing completion for others.

4. B-vitamins. Summarization of data and derivation of representative values for a publication on pantothenic acid, vitamin B₆ and vitamin B₁₂ are now complete for some 700 items of food. The values will provide the basis for evaluating food supplies and diets with respect to these vitamins.

C. Nutritional Requirements

Adolescent girls. The data obtained in a study to measure the metabolic response of adolescent girls to a controlled ovo-lacto-vegetarian diet have been analyzed statistically, (see 1966 report, p. 220). A manuscript reporting the results is in preparation. In this study, under a research contract with Andrews University at Berrien Springs, Michigan, 16 girls, 17-19 years old, ate a controlled diet for 25 days. Intake and excretion of nitrogen, fat, calcium, phosphorus, and magnesium, serum levels of cholesterol, phospholipids, glycerides, and total fatty acids were measured. All girls were in positive nitrogen balance on intakes of 64 grams protein per day. Calcium balances showed that the girls (average age 18 years) had requirements that could be met by the NRC recommended allowance of 1.3 grams calcium for older adolescents (17 and 18 years) but not by the lower allowance of 0.8 grams for 18-35 year old women. Small positive magnesium balances achieved on 320 mg magnesium/day indicated the probable need for an upward revision of the intake level currently believed to be adequate for maintenance.

D. Food Consumption and Diet Appraisal

1. 1965 nationwide survey. Analysis of the household data showed that families surveyed in the spring of 1965 spent 36 cents of their food dollar for meat, poultry, fish and eggs; 19 cents for vegetables and fruits, including juices; 13 cents for milk and milk products; 12 cents for flour, cereals, and bakery products; 10 cents for beverages other than milk and juice; and 10 cents for fats, sweets and all other foods. This division of the food dollar varied little among groups of families, whether classified by region, urbanization or income. Choices within these broad groups

did vary. For example, farm families used more flour, fat, sugar, and eggs per person and less bakery products than city families. Southern families used the most pork, poultry, and fish and the least beef; western families used the most beef.

Families surveyed in the spring of 1965 used more beef and poultry and less pork, fish and eggs than families surveyed in the spring of 1955. The families surveyed in 1965 also used more frozen milk desserts, cheese, dry and fresh skim milk and less fresh whole milk, cream, and evaporated milk; more canned and frozen vegetables and fruits and less fresh vegetables and fruits; more breakfast cereals and bakery products other than bread and less flour, bread and cereals other than breakfast cereals; more margarine and oils and less butter and shortening. Many of the changes reflected the trend to increased use of commercially prepared foods. There was also greater use in 1965 of foods associated with snacking--ades and punches, soft drinks, potato chips, luncheon meat, peanut butter, crackers, cookies, doughnuts and candy.

Papers reporting findings on the food consumption of households in spring 1965 were presented at three National meetings. One preliminary report was published and a second was prepared for publication. Final reports are in preparation--one for the U.S. as a whole and one for each of the four census regions. These reports will provide information on the percentage of families using major groups, subgroups, and selected items of foods as well as the quantities and money value of the foods consumed. The information will be given separately for urban, rural nonfarm, and rural farm families and for all urbanizations combined. Another classification will be by income of family.

2. 1967 survey in Mississippi. In May 1967, a survey was made to evaluate two types of food distribution programs in two counties in the Mississippi Delta. The survey was made by the Consumer and Food Economics Research Division, ARS, in cooperation with the Economic Research Service. In Washington County, a Food Stamp Program had replaced a Food Donation Program in March 1967. In Sunflower County, a Food Donation Program of long standing was in operation. The families surveyed included participants and eligible nonparticipants in both the Food Stamp Program and the Food Donation Program.

Preliminary evaluation of the data indicated that the average diet was poor. Foods most needed to improve the diets of these families are milk products, vegetables and fruits. Diets of families who participated in the food program were similar in many respects to diets of those who were eligible but did not participate.

Money value of the food used averaged about \$4.00 a person a week (including value of free food stamps and donated commodities). This is about 25 percent less than the cost of the USDA Low-cost Food Plan for the South. On the average the families included in the survey spend about one-half of their incomes on food.

Data on height and weight were obtained as an indication of the growth and nutritional status of children 2 to 12 years old in the families surveyed and are being evaluated by the Human Nutrition Research Division. The children tended to be somewhat short for their age and also heavy for their age and for their height. Children in families that were participating in a food program were no different in height and weight for age than children in nonparticipating families.

3. Preschool children in Hawaii. Data needed to assess the nutritional situation of children 2 to 3 years of age in low-income families and middle-income families in Honolulu have been collected. Included are a 3-day record of the child's food intake, a physical examination record, and information on the child's early diet, on the mother's food practices and attitudes, and on the family's socioeconomic situation. Data collected in biochemical, clinical, and psychomotor tests are being evaluated. The research is being carried out by the University of Hawaii under cooperative agreement with the Consumer and Food Economics and the Human Nutrition Research Divisions.

4. Nutritive value of the national food supply. Food energy (calories) and selected nutrients provided by the per capita food supply are estimated each year by the Consumer and Food Economics Research Division from data on apparent civilian consumption, retail basis, developed by the Economic Research Service. The estimates show that shifts in food consumption over the years have resulted in changes in the sources of fat, carbohydrate and protein. Vegetable fat now accounts for a higher percentage of total fat because of the shift from butter to margarine and from lard to shortening and the sharp increase in use of salad and cooking oils. The share of calories derived from total nutrient fat which increased from 1909 to the early 50's has changed little since. Saturated fatty acids account for a smaller share of the total fat today than they did 55 years ago--37 percent compared with 40 percent--even though the American diet now contains more fat. Oleic acid continues to account for about 41 percent of the total fat. The share attributed to linoleic acid has been increasing and is now roughly 13 percent. Starch and sugars now contribute about equally to total carbohydrates; in 1909-13, two-thirds was provided by starch and one-third by sugars. Animal products contribute two-thirds of the protein today compared to one-half 55 years ago.

5. Nutrient content of school lunches. A nationwide study of the nutrient content of Type A lunches served to 6th graders is being carried out by the Consumer and Food Economics Research Division in cooperation with the School Lunch Division, Consumer and Marketing Service. The study was undertaken to obtain data needed for evaluating the Type A pattern. Twenty lunch composites from each of 300 schools in 19 states in 5 geographic regions have been analyzed by a contractor, the Wisconsin Research Alumni Foundation, for proximate composition, fatty acids, and 12 minerals. Analyses are in progress for seven vitamins, iron and residues of chlorinated hydrocarbon insecticides.

In general, the lunches met the nutritional goal of one-third of the 1963 NRC Recommended Daily Dietary Allowance for 9 to 12 year olds for energy, calcium and protein. The average energy level of the lunches from the 300 schools was 735 Calories--the goal for girls and a little under the goal of 800 Calories for boys. On the average, 39 percent of the calories were provided by fat in the lunches. The average calcium content was 400 milligrams per lunch--a little more than the goal of 367 milligrams. For protein, all lunches met the goal of one-third of the Recommended Daily Allowance for 9 to 12 year olds--18.3 grams for girls and 20 grams for boys.

6. Acceptance of Type A Lunches. A study of factors affecting acceptance of the lunch program by 10th grade students in Louisiana is being carried out under cooperative agreement with Louisiana State University. Thirty students from each of 17 schools, their parents and the officials of the schools provided information for the study. Included were urban and rural schools, large and small schools, and schools with low, medium and high levels of participation in the lunch program.

E. Support for Food and Nutrition Programs

1. The fifth national Nutrition Education Conference was held in Washington, D.C., February 20-22, 1967, with about 275 persons representing a wide variety of agencies and disciplines from most of the states. The theme was "effective communication" and coordination of nutrition programs as a means of facilitating behavioral changes in eating habits. The Conference was cosponsored by the Consumer and Food Economics Research Division and the Interagency Committee on Nutrition Education.

2. Bimonthly publication of Nutrition Program News, which reaches some 7,000 workers in nutrition and related fields was continued.

3. Technical assistance to programs. Nutrition research findings continue to be studied and interpreted for application to problems in food selection and food use. Technical assistance was given by nutritionists to programs of other government agencies such as the food and nutrition programs of Project Head Start, Office of Economic Opportunity. A 130-page manual prepared by the Human Nutrition Research Division for the Head Start Program gives quantity recipes and food buying guides needed to prepare nutritionally adequate meals for groups of 25, 50, or more preschool children from low-income families.

Talks to groups involved in community nutrition programs, radio and TV tapes on nutrition, and consultant help and participation in conferences contributed to coordination and strengthening of nutrition programs.

4. Food for low-income families. Recipes were developed for selected commodities by the Human Nutrition Research Division for distribution to low-income families participating in the USDA food distribution program or the Food Stamp Program. These supplement an earlier series of 17 leaflets on a variety of commodities and now available for national distribution as part of the Department's participation in the Federal program to combat poverty.

5. National school lunch program. Research on large quantity food preparation and food quality in the Human Nutrition Research Division has provided help to school lunch managers across the nation to make the best use of donated food commodities available to them and other foods obtained on the local market. A survey of pupil acceptance of "favorite" recipes is in progress in about 100 schools in five areas of the United States.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

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CITRUS AND SUBTROPICAL FRUIT UTILIZATION - FOOD

Southern Utilization Research and Development Division, ARS

Problem. The citrus and subtropical fruit production of the Southern Region is an expanding industry with the need for the development of better--as well as new--consumer products and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits to the economic advantage of the growers, processors, and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils; flavonoids, including bitter constituents; constituents responsible for oxidized off-flavors; carotenoids; and the like, which determine many of the sensory characteristics and affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, and fermentation. There is also need of an adequate method for estimating the amount of peel solids in various citrus products to allow for better control.

Increased production of citrus has stimulated the development of new products, but many of these are urgently in need of improvement, which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change; to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products, and comminuted whole fruit products; and to develop new or improved canned products that have a natural fruit flavor. Research is especially needed on grapefruit to develop practical methods for reducing the bitterness and harshness of juice products and to increase the use of grapefruit juice base in mixed fruit juice blends, drinks, and concentrates. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials to obtain and maintain the most desirable fruit characteristics, particularly for citrus powders.

In addition to the work on citrus, research is currently needed to develop new processed products from avocados.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research on chemical composition is conducted under contract by the Stanford Research Institute, South Pasadena, California, and is supervised by the

U. S. Food Crops Utilization Research Laboratory, Weslaco, Texas. It involves development of an oxalate or other organic acid index for estimating the amount of peel solids in orange and grapefruit paste, puree, and juice products.

Research to develop basic information on the chemistry of flavor of citrus and subtropical fruits and their products and byproducts is conducted at Weslaco, Texas, and at Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food products and processing technology. At the Weslaco Laboratory, the program includes investigations of the influence of seasonal changes of carotenoid and flavonoid constituents that directly or indirectly affect flavor and color of processed products from Texas colored grapefruit, as a basis for improvement of processing characteristics of and products from these grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR, ARS, Weslaco), the Texas College of Arts and Industries, and Rio Farms, Inc. (Edcouch) are providing grapefruit of known history and conducting--or cooperating in conducting--on-the-tree tests. At the Winter Haven Laboratory, the program includes: an evaluation of the flavor contribution of peel flavones to orange juice and identification of unknown peel flavones to develop improved orange juice products; investigations of the composition of essential oil in citrus products, particularly orange, to afford a basis for maintaining and improving the quality and uniformity of citrus products; a study of off-flavor development in processed citrus juice in relation to the lipid composition of the suspended matter; a study of the enzyme reactions in fresh and processed citrus to increase the natural flavor of citrus products; and exploration of means to minimize or block the formation of bitter components in grapefruit, a key step in developing processed grapefruit products of greater attractiveness to the consumer. Close consultation is maintained with the Florida Citrus Commission (Lakeland); the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred); Citrus Research Investigations (CR, ARS, Orlando); Florida Citrus Mutual (Lakeland); and the citrus processing industry. Contract research on flavor, supervised by the Winter Haven Laboratory, is being carried out by the Ohio State University Research Foundation, Columbus, Ohio. It is a study of nonenzymic browning in model systems to develop methods of blocking the reactions involved in flavor deterioration of orange juice crystals.

Research to develop new and improved process and product technology is carried out at Weslaco, Texas, and Winter Haven, Florida. At Weslaco, comminuted whole fruit, powders, pastes, purees, and beverage products are being developed from oranges and grapefruit to improve processing efficiency and to diminish pollution problems. This Laboratory is also investigating factors that affect the stability of a freeze-dried avocado salad product, particularly the lipid constituents. The citrus and subtropical fruit research is being carried out in part in cooperation with several state and

private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Formal agreements exist with the Texas Agricultural Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco), and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Cannery Association (Weslaco), and other organizations as necessary for the procurement and processing of fruit. At Winter Haven, the application of freeze drying to citrus and other subtropical fruits to develop new and improved products is being studied. Also, improving the commercial utility of the foam-mat process for production of citrus crystals is being investigated. This latter research is conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding. Contract research on process and product development, supervised by the Weslaco Laboratory, is being carried out at the Citrus Experiment Station, University of Florida, Lake Alfred, Florida. It pertains to the development of a practical and efficient pilot plant-scale process for the production of enzymatically debittered grapefruit juice and products with improved flavor, product stability, and storage characteristics.

The Federal in-house scientific effort at the Southern Division devoted to work in this area totals 17.8 scientific man-years. Of this total, 10.3 is devoted to research on flavor and 7.5 to technology--process and product development. The contract research involves an additional 0.6 scientific man-years on chemical composition and physical properties, 0.6 on flavor, and 0.3 on technology--process and product development.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 23.4 scientific man-years is devoted to citrus and subtropical fruit utilization research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Flavor

1. Enzyme Reactions Involved in Development of Citrus Flavor. Enzyme studies directed toward increasing the flavor of citrus products were recently initiated. Several techniques are being investigated to isolate from grapefruit the mitochondria, which contain many of the enzymes--oxidoreductases--involved in the development of citrus flavor. Isolation and functional characterization of these enzymes should contribute to a practical method of improving the flavor of processed citrus. Orange and grapefruit juice vesicles are being assayed enzymatically for the pyridine nucleotides, which are coenzymes for most of the oxidoreductases and have other important functions in many biosynthetic pathways. (S3 2-60).

2. Chemical and Physical Properties of Flavoring Constituents of Citrus and Subtropical Fruit Products. In research on the composition of essential oils in citrus products, experiments have established the quantity of nootkatone that can be added to grapefruit juice to improve its flavor and aroma, a threshold of five or six ppm. However, if the level was increased much above eight ppm, an unpleasant taste resulted. In another area of the research, a number of constituents of cold-pressed orange oil have been isolated and identified. Two new ketones--piperitenone and 6-methyl-5-hepten-2-one--have been identified. Other oxygenates identified are carvone, nootkatone, α -sinensal, β -sinensal, decanal, undecanal, geranial, and neral. A new monoterpenoid aldehyde was also isolated, and a sesquiterpene fraction was identified as a mixture of valencene isomers. Anhydrous orange essence and terpeneless orange oil were prepared and the major components identified; these two materials are expected to improve the flavor of "foam-mat" dried orange juice. (S3 2-48, S3 2-55).

3. Investigation of the Bitter Constituents and Flavonoids in Citrus Products. Considerable amounts of the five known flavones from the neutral fraction of orange peel juice extract are needed for taste evaluation of their contribution to orange juice flavor. In addition to the heptamethoxyflavone and tangeretin already available, nobiletin has now been obtained in quantity. A method has been devised for preparing sinensetin and tetra-O-methylscutellarein, and efforts are continuing to obtain sufficient amounts for taste evaluation of their contributions to orange juice flavor. Fruit samples from orange trees of known variety and rootstocks are being selected, and their juice and peels frozen for eventual analysis of the bitter constituent limonin. (S3 2-47, S3 2-54).

Two ingenious ways to introduce radioactive precursors into grapefruit leaves and stems have been devised. One of the more promising methods includes a separation of the leaf from several centimeters of the main vein starting at the tip end of the leaf, leaving the leaf attached to the plant. The section of vein free of leaf is immersed in the solution of radioactive material, which is expected to be taken in through the vein. Another method consists in forming a hole in the stem in such a manner as not to cause air blockage of the phloem and xylem tubes, thus allowing for the possible uptake of a solution. The results of these experiments are not definitive as yet. This work will ultimately help determine not only the metabolic pathways of the synthesis of naringin, a bitter component, but also the subsequent use of possible inhibitors. In another phase of the research, the relation of age to the ratio of naringin to naringenin-7 β -rutinoside (tasteless) in leaves and fruit is being determined to provide information that could aid in the preferential conversion of naringin to its tasteless isomer. Tissue culture procedures and use of cell-free enzyme systems have greatly facilitated the study of the precursors, synthesis, and metabolism of naringin in grapefruit tissues. (S3 2-49).

Studies have continued on the influence of seasonal variations in color and flavor of Texas colored grapefruit on the quality of its processed products.

A new highly red-colored seedy grapefruit, Hudson Foster Pink, appears promising for yielding more colorful sections to be used in chilled and canned products--and over a longer harvesting time. Its frozen sections also undergo less weeping and softening than those prepared from Redblush grapefruit. Under extremely long storage, the Hudson does not become insipid as other red varieties do. The effect of fruit age and time of fruit set on flavonoid and liminoid content is also being studied. Preparation of a sample by hard-freezing it with dry ice, grinding both sample and ice, and then removing the ice may have commercial application for comminuting food products with resilient or tough tissue. In another area of the research, two methods have been developed for obtaining reasonably high and enduring flowrates through columns of Polyclar AT resin. One method, which produces a resin that absorbs flavonoids to a greater degree than the original resin, may therefore be more useful in debittering. (S3 2-51).

4. Development of Off-Flavor As Related to Lipid Composition. In preliminary research on a recently initiated project on off-flavor development in citrus juice as related to lipid composition, an off-flavor was noted in an orange concentrate stored for three months at 85°F, but there was no difference between the general lipid thin-layer chromatographic profile of this concentrate and that stored at 0°F. (S3 2-50(Rev.)).

B. Technology--Process and Product Development

1. Application of Foam-Mat Drying to Citrus. Cooperative research is being conducted with WU and the Florida Citrus Commission to improve the commercial utility of the foam-mat process for producing citrus crystals. Experimental foaming methods have made it possible to use very low viscosity concentrates that were previously unsatisfactory for foaming. Fourteen compounds isolated from the acid degradation of fructose have been identified as products of storage deterioration in orange crystals. Compounds formed from ascorbic acid may also be a source of off-flavor. Several types of flavoring additives, including essence, essence oil, and sweeteners, are compatible with foam-mat dried orange and grapefruit crystals. The storage life of orange crystals is lengthened slightly by use of higher oil levels or by the incorporation of grapefruit crystals. The fact that untrained tasters generally prefer higher levels of oil in orange crystals suggests a possible means of enhancing storage stability through the addition of oil. (S3 2-43, S3 2-59).

2. Process for Enzymatically Debittering Grapefruit Products. From contract research conducted by the Florida Agricultural Experiment Station is stemming the first evidence that an enzymatic debittering process has practical potential for reducing the bitterness of grapefruit products. Naringin in grapefruit juice can be reduced by immediate removal of the pulp, which represents only about 10% of the original volume but has a relatively high naringin level. Because of its small volume, the pulp could be economically debittered with naringinase. A feasible process may consist of removing the pulp from the juice, debittering it, and then adding it back. A low level

of naringinase could be used to debitter chilled grapefruit sections if they were stored for several weeks before use. (S3 2-46(C)).

3. Freeze-Dried Products from Citrus and Subtropical Fruits. Orange and grapefruit juices, strawberries, and guava paste have been freeze-dried in preliminary runs. There seems to be a direct relationship between the physical form of a product and the rate at which it may be freeze-dried. Melting point data were obtained on various food products by use of AC and DC resistance measurements; however, the difficulties inherent in these measurements for very low temperatures must be overcome before the data is reliable. Measurement of low temperatures was also attempted by differential scanning calorimetry, which gave more reliable values than those obtained by the resistance method. (S3 2-53).

Small samples of frozen avocado salad were freeze-dried to moisture contents varying from 0 to 8% and placed in storage at 100°F under an atmosphere of air. Analysis for peroxide values and free fatty acid contents after storage indicated that a product containing 2 to 3% moisture developed a minimum of peroxides and free fatty acids. The freeze-dried material reconstituted rapidly and retained its original fresh flavor. Also, semi-commercial quantities of frozen avocado salad were freeze-dried at a commercial plant and sealed in enameled cans under atmospheres of air, nitrogen, and vacuum. Air packs were judged unacceptable after the following storage periods: 100°F, 2 weeks; 70°F, 10 weeks; 40°F, 16 weeks. The nitrogen and vacuum packs stored at 70°F for 24 weeks were judged to have acceptable flavor. All samples stored at 100°F and 70°F were judged to have unacceptable flavor characteristics after 32 weeks' storage. (S3 2-52).

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CITRUS AND SUBTROPICAL FRUIT UTILIZATION - FOOD

Western Utilization Research and Development Division, ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from almost all of the navel oranges, contains substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

USDA AND COOPERATIVE PROGRAMS

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California; at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California; at the University of Hawaii, Honolulu; by contracts at Riverside, California, and Tucson, Arizona and under P.L. 480 in India. Investigations are conducted on the composition of citrus essential oils, the flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, the enzyme systems that are involved in the appearance or disappearance of constituents and structures of plant tissues, and the constituents of dates that affect the quality and stability of products. The findings of such research are applied in the development of new and improved citrus, tropical, and subtropical fruit products.

The Federal program of research in this area totals 10.6 scientist man-years, including contract research. Of the total, 1.7 are assigned to investigations on chemical composition and physical properties; 3.3 on flavor; and 5.6 on technology--process and product development. The Division supervises one research project supported by a P.L. 480 grant.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 23.4 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Lemon Oil and Juice Products of Improved Stability. We are conducting research to determine the relationship of the constituents of lemon to the flavor, color, and stability of products.

Ultraviolet-fluorescing compounds in cold-pressed lemon and lime peel oils were separated by thin-layer chromatography (TLC) into patterns distinctly different from those of cold-pressed bergamot, orange, grapefruit and tangerine peel oils. To differentiate between lemon and lime oils, two-dimensional TLC was employed. Also, we tested several methods of isolation and analysis of nucleic acids and nucleotides of lemon juice. A study of the effects of the preservatives, sulfur dioxide, benzoate and sorbate, and storage conditions on the analytical procedures developed to characterize lemon juice indicates that published methods may be used except for formol titration where the aliquot must be boiled 1 min. to expel sulfur dioxide. The B peak used to determine the phenolic content of the juice is not affected by addition of sorbate. Amounts of citric acid, amino acids, malic acid, and total phenolics remain constant up to 118 days' storage at 20° C.

At the University of Baroda in India, a study of carbohydrate metabolism and formation, and the accumulation and breakdown of organic acids in citrus is supported by P.L. 480 funds. To test the hypothesis that organic acids in citrus fruits originate by enzymic conversion from carbohydrate in fruit vesicles, lemons (Citrus acida) were studied to determine the sites of enzymes and intermediates concerned with glycolysis and ascorbic acid synthesis. Outer skin, inner skin, vesicles and fruit juice were analyzed. All areas of the lemon appear to possess metabolic systems to synthesize ascorbic and citric acid.

2. Date Composition and Products. Three systems are involved in the darkening of dates: sugar browning, enzymic oxidative browning of phenolic constituents, and nonenzymic oxidative browning of tannins. Under a recently completed project, we have determined that the main enzymic browning substrates in dates are three isomeric monocaffeoylshikimic acids. All are newly discovered compounds not found in other common fruits. Numerous flavans also occur in

small amounts in immature dates (but not in mature dates) and all are enzymic browning substrates. One of these, shown to be epicatechin, disappears during fruit maturation, suggesting that it may be partly responsible for the characteristic golden-brown color of ripe dates.

Our research on the three main browning systems of dates indicates the role played by each during ripening, processing and storage. As the green date softens during ripening, the concentration of phenols decreases as a result of enzymic browning, and the fruit becomes light-brown. Later in the season when the fruit dries on the palm, the browning enzymes are probably inhibited by the low moisture content so that enzymic browning is slowed. Thus, dry fruit having a very light or slightly greenish color has probably dried to a low moisture content before sufficient enzymic browning could take place. After hydration and an intermediate storage period, the fruit is medium brown, and the phenolic-enzymic-browning substrates are no longer detectable. Thus, it appears that enzymic browning of naturally occurring phenols is mainly responsible for the brown color of ripe dates and also contributes somewhat to browning during processing and early storage. It does not appear to be responsible for the very dark color of dates stored a long time.

Because their reaction rates are slow at normal temperatures, tannin browning and sugar browning appear to be most important during heat processing and during storage after processing. Brown-pigment precursors probably form during heating and lead to brown pigments during subsequent storage.

Since color is most easily developed during heat processing, this step affords the best opportunity to achieve color uniformity, but improper heat processing, particularly the use of high temperatures, can be detrimental. Because color is most stable in dry dates, field-dry fruit is best for storage. Once the fruit is hydrated, color begins to darken, and fruit stored for different periods differ in color. The small color variations of fruit stored dry can be largely equalized by controlled heat processing. High quality dates, which usually require little or no hydration, frequently have a greenish cast and color variability that can be improved by a short heat treatment at about 120° F. Reddish off-colors sometimes occur in dry dates that required long hydration and processing periods. These off-colors can be prevented by avoiding temperatures above 140° F.

The date industry has repeatedly observed that some processed dates attain a better flavor than others, but the reasons were not known. We found that dates increase in acidity during processing, and since flavor may be related to acidity, we investigated treatments, such as heat, that increase the acidity. By carefully controlling time, temperature, and moisture content, we achieved appreciable flavor enhancement. In dates at 22-28% moisture, flavor was easily enhanced, but it was difficult in dates at low moistures (14%). Temperatures above 140° F. were detrimental to flavor, but 120° F.

was beneficial. Dates with 22% moisture reached optimum flavor in 3 days at 120° F.; longer treatment produced off-flavor. The flavor of diced dates, generally quite weak, can be greatly improved by holding the product 3 to 5 days at 100° F. The industry now uses this process. All of these treatments increased the acidity of date tissue,

To determine why the acidity of dates increases during processing, we studied the organic acids of dates. In immature fruit, malic acid represented about 75% of the ether-soluble acids. Other free acids included phosphoric, citric, and galacturonic. Bound acids included shikimic, glycolic, and galacturonic, together representing about 4% of the total ether-soluble acid fraction. Quinic acid was not detected. The unique presence of caffeoyl-shikimic acids in dates appears to be related to the presence of shikimic acid and absence of quinic acid, an unusual circumstance since most common fruits contain significant amounts of quinic acid. Although the acids of processed dates remain to be determined, it appears that enzyme hydrolysis of bound acids (including those not soluble in ether) may be responsible for the increasing acidity during processing and storage.

B. Flavor

1. Control of Bitterness in Navel Orange Juice and Concentrates. The Stanford Research Institute at South Pasadena, California is conducting contract research to develop a practical rapid assay method to measure individual limonoid constituents. Industry needs such a method to help control the bitterness of navel orange products,

An analytical procedure for determining limonin in citrus juice has been simplified to make it more suitable for routine use. The procedure has been used to measure the limonin content of freshly squeezed navel juice, aged juice, and commercial juice and concentrate. The juices were also evaluated by a taste panel to determine their degree of bitterness. Good correlation was obtained between bitterness and limonin content. The taste threshold for limonin was 4 to 5 ppm. Navel oranges on Trifoliate rootstock seem to develop less bitterness than those on Troyer or Cleo rootstocks. The limonin in navel oranges is concentrated (78-98%) in the peel, rag and seeds.

2. Sweeteners from Citrus Concentrates. We are investigating the flavonoids and bitter terpenoids of citrus fruits, particularly navel oranges. A new sweetener, hesperetin glucoside dihydrochalcone, has been prepared starting with the hesperidin flavonoid. It has about the same sweetness as naringin dihydrochalcone, but its sweetness is less clinging. Since hesperidin is the cheapest and most accessible citrus flavonoid, a sweetener prepared from it may be economically more attractive than the earlier dihydrochalcone sweeteners. The bitter flavonoid naringin can be converted directly to neohesperidin dihydrochalcone, the sweetest dihydrochalcone in this series. A new flavanone, eriodictyol neohesperidoside, has been isolated from Seville oranges,

Studies on the photochemistry of limonin have shown that it can be converted to two photoproducts, photolimonin I and II, which have little or no bitterness. The structures of these compounds have been determined. The photochemical conversion of bitter limonin to tasteless (or nearly tasteless) photoproducts suggests a possible route for debittering navel orange juice. The structure of another naturally occurring limonoid, rutaevin, has been determined as 6-keto-epilimonol.

C. Technology--Process and Product Development

1. Concentrates and Powders from Hawaiian Fruit. The development of concentrated Hawaiian fruit products would reduce packaging and transportation costs, build mainland markets, and help diversify Hawaiian agriculture. At our Hawaii field station, we are studying methods to reduce the bulk and weight of tropical and subtropical fruits while retaining high quality. Banana puree stabilized by addition of 200 ppm. sulfur dioxide, heat inactivation of enzymes, and addition of citric acid and 100-200 ppm. potassium sorbate has retained its original high quality for at least 3 months at 35-40° F. Taste panel tests showed that 250 ppm. sorbate may affect the flavor adversely but 100 ppm. was not detected. The puree made from Hawaii-grown bananas would be suitable for use in bakery and dairy products. Five hybrids each of guavas and passion fruit were processed into beverage products for quality evaluation to assist in selection of varieties for expansion of commercial acreage. Inactivation of enzymes in passion fruit juice by rapid heat exchange enhanced the quality of the juice. Stability of papaya nectar, passion fruit nectar and guava jelly held at 35° to 100° F. is being evaluated by taste panels. Guava jelly at 100° F. deteriorates rapidly, about 11 times faster than jelly at 55° F.

Research at the Instituto de Investigaciones Technologicas, Bogota, Colombia, supported by P.L. 480 funds has been concluded. Thirty-seven compounds were identified in guava essence and 18 in that of curuba. However, none of these compounds possessed the characteristic aroma of the fruits. Several attempts were made to "lock-in" the essences into natural inert carriers. To "lock-in" the essences, the processes which required low temperatures or very short times of operation gave better results. The stability during storage and ability to subsequently restore the aroma was dependent upon the kind of carrier and type of process followed to enclose the essence.

2. Use of California-Arizona Desert Grapefruit in Juice Blends and as an Acidulant in Food Manufacture. We are conducting research to isolate, identify and characterize nitrogenous compounds, carbohydrates and flavonoids that affect the color or flavor of desert grapefruit grown under known conditions. Also we are investigating the metabolism of these compounds, changes in them during processing, and the physiological activity of selected compounds. The data obtained will be a guide for processors in improving grapefruit products, pharmacologists in evaluating reputed physiological

activity, and plant breeders in developing varieties suited to processing. A previously unrecognized compound in grapefruit was isolated and identified as dihydrokaempferol. It co-occurs with naringenin and kaempferol (following hydrolysis) in all actively metabolizing grapefruit tissues studied, including very young fruit, young growing leaves, and young twigs. This finding supports the postulated biosynthetic pathway: flavone → dihydroflavonol → flavonol. In our investigation of grapefruit color changes, we found that the green peel of Marsh grapefruit and green plants contain the same major carotenoids. However, as the fruit ripens, its chlorophyll disappears and carotenoids accumulate. Comparison of mature early and mature mid-season fruit showed that inhibition or blockage between phytoene and phytofluene prevents the formation of colored carotenoid pigments. The nature of this inhibition is not yet known but it is, apparently, the reason for the light color of ripe desert grapefruit.

In contract research at the University of Arizona in Tucson, new food products using desert grapefruit and blends of grapefruit with other foods are being developed. Grapefruit plus juice packaged in glass containers, heated to 185° F., cooled rapidly, and stored at 40° F. or below had a shelf-life of well over 6 months with little or no off-flavor from heating. Grapefruit juice blended with peach and apricot juices and vacuum packed in enamel-lined cans retained color and flavor for long periods at 40° and 80° F. Blends of grapefruit juice with juices from frozen strawberries, raspberries, boysenberries, and olallieberries continue to enjoy high acceptance. These blends are most stable in glass containers, but they do not have long shelf-lives at high temperature. Blends of guava puree and grapefruit juice appear promising. Apricots canned with 10-20% of grapefruit juice in the sirup retained their color and flavor for over a year. Addition of grapefruit juice to apricots and peaches appears to enhance the flavor of both canned fruits and nectars. Grapefruit juice as normally prepared has a bitter flavor at limonin levels from 8-12 ppm. Juice prepared to avoid incorporation of juice sacs, membranes, and peel juice appears to have considerably lower limonin levels.

A second contract research program at the University of Arizona, Tucson will seek to improve the quality, convenience and stability of Arizona-California desert grapefruit products.

3. Processing Mechanically Harvested Dates. The University of California at Riverside is conducting contract research to improve the quality of mechanically harvested dates. In comparing tender and tough dates they found that tough dates have a lower moisture content and lower glucose and fructose levels, but a higher sucrose level. Total sugar contents of tough and tender dates are similar, as are pectin fractions, lignin content, hemicelluloses, cellulose, and nitrogen assays of 80% ethanol extracts and residues. Mesocarp parenchyma cell walls become highly disorganized as the fruit ripens. The degree of disorganization is not as pronounced in tough dates as in tender dates, which may account for the toughness of the drier dates.

We are conducting research to develop economically feasible methods for processing mechanically harvested dates, which vary widely in degree of maturity. Dates harvested in 1966 at three stages of maturity were separated by differential flotation in sucrose solutions of various concentration. Then they were frozen at 0° F. and held 1 to 3 days. This temperature was used because at 15° F. freezing was incomplete and at -20° F. ripening was not induced. After freezing, the dates were tempered 2 to 3 days at 34° F. During tempering, they began to take on a translucent appearance indicative of ripening. After tempering they were exposed to air ranging from ambient temperature to 120° F. Ripening was less satisfactory (except in some more mature grades) at higher temperatures, perhaps because of dehydration. Separations have also been made of dates fully ripened on the palm (corresponding to those now received at processing plants). A diverging roller separator was developed that eliminates unpollinated and cull dates and separates the remainder into three size grades, which are then separated by differential flotation in water to give six grades.

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DECIDUOUS FRUIT AND TREE NUT UTILIZATION

Eastern Utilization Research Development Division, ARS

Problem. Lack of knowledge of the nature and quantities of the various chemical constituents and enzyme systems present in fresh fruits, and of the changes these undergo during processing, is a limiting factor in research designed to develop new and improved products and processing techniques. Knowledge is required on the composition and physical structure of fruits and fruit products, with emphasis on substances responsible for color and flavor, vitamins, and other constituents important in determining consumer acceptance and nutritive value of the products. Composition should be studied in relation to variety, stage of maturity, and environmental conditions of growth; and to changes occurring between harvesting and processing, during processing, and in storage and distribution. Recently developed equipment and techniques have made it possible to isolate, separate, and identify constituents that could not have been handled previously. As basic information is developed, new processing techniques will be applied in the improvement of fruit products, and in more efficient utilization of by-products from fruit processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving chemists, biochemists and chemical engineers engaged in both basic and applied research related to fruit processing and fruit products.

The Federal scientific effort devoted to research in this area totals 8.5 scientist man-years. Research on chemical composition and physical properties involves 0.6 scientist man-year, including effort equivalent to 0.2 scientist man-year under a grant at Temple University on the metabolism of red tart cherries. Effort on flavor research amounts to 1.1 scientist man-years, and research on color, texture and other quality factors involves 2 scientist man-years. Research on processing characteristics of Eastern pears will be conducted under a contract with Rutgers University, New Brunswick, New Jersey. Research on technology - process and product development involves 4.8 scientist man-years.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 38.5 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

Contract research at the Maryland Agricultural Experiment Station, College Park, is now complete. This research showed that the calcium firming of apple slices appears to be due more to a complex of calcium with hemicellulose or cellulose rather than a calcium pectin combination. The pentosan-hexosan-

polyuronide complex, previously shown to be correlated with texture of canned apple slices, was found to be mainly α - and β -D-xylose and α - and β -L-arabinose plus small amounts of galactose, glucose and galacturonic acid. Stored apples contained small quantities of pectin esterase but no polygalacturonase. Autoradiography of apple slices treated with radioactive calcium is a useful technique for studying the calcium penetration and firming as effected by various processing methods. The firmness of canned slices was improved by vacuum treatment.

In grant research at Temple University, study of the metabolism of bruised and unbruised cherries by means of radioactive metabolites continued. Ripe cherries were subjected to bruising and injected with specific C^{14} labelled compounds. The rates of production of $C^{14}O_2$ and total CO_2 were determined. The fruit was then frozen for subsequent study of the various fractions developed during the research. Mature red tart cherries harvested with a portion of the stem attached were "fed" through the stem with three C^{14} labelled compounds. The fruit was then bruised and held for one hour or 24 hours. The various extracts and insoluble residues will be fractionated by suitable techniques to determine where C^{14} activity resides.

B. Flavor

Study of the composition of 150-fold Montmorency cherry essence showed the most volatile fraction to consist of acetaldehyde with smaller amounts of propanal, 2-methyl propanal, methyl acetate, methanol, ethyl acetate and diethyl ether. In all, there appeared to be more than 120 compounds present as shown by gas chromatography. Thirty compounds have been identified, including 9 alcohols, 7 carbonyl compounds, 6 esters, 3 terpenes, 4 aromatic compounds and benzoic acid.

C. Color, Texture and Other Quality Factors

Negotiations with the New Jersey Agricultural Experiment Station, New Brunswick, on the processing characteristics of Eastern pears are nearly completed. It is expected that experimental studies will begin with the 1967 crop.

The mechanical harvesting of cherries was a decisive factor in handling the 1966 crop. Mechanical harvesting reduced labor costs to growers by more than \$1 million and made possible harvesting of about 7% of the national crop which would not have otherwise been harvested.

D. Technology - Process and Products Development

The explosion-puffing of four types of apple pieces, 2 sizes of dice, segments and half-segments (16ths halved transversely which are the best shape for most uses), indicated that the half-segments are the most versatile and provide highest yields. The output of this product from the explosion gun is suitable for making instant applesauce. Where uniformity is important, air classification can satisfactorily separate the small percentage of partially

puffed and irregularly shaped pieces. Porous apple pieces intended for use as snacks are normally hygroscopic, but new processing techniques are solving this problem. Blueberries can be explosion-puffed at any season if they are dried to 12-15% moisture and stored at room temperature.

Laboratory scale tests show that apples can be peeled by a combination of hot isopropyl alcohol (to remove wax) followed by treatment with dilute alkali. However, apples thus processed did not produce a satisfactory applesauce because the lye did not remove the calax which appeared as black specks in the applesauce. Since mechanical peeling is not practical for apples below a certain size, the harvesting of undersized fruit expected from mechanical harvesting provides a powerful stimulus for the development of other peeling methods for such undersized fruit.

Irradiation by ultraviolet light appears to be a useful way to reduce a low initial microbial count in cider. In the study a 1/8-inch layer of cider was pumped through a shell surrounding the ultraviolet lamp. The exposure time varied between 11 and 40 seconds and the longer exposure reduced the microbial count by 99%. A taste-panel evaluation showed no detectable change in flavor after UV radiation. This new process may permit distributors to market fresh cider without using chemical preservatives and the development will be brought to the attention of cider producers.

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DECIDUOUS FRUIT AND TREE NUT UTILIZATION

Southern Utilization Research and Development Division, ARS

Problem. The peach industry in the Southeastern United States is dependent to a large extent on the fresh market. A peach processing industry is needed in the Southeastern states to provide a profitable market for more of the edible peaches that do not meet fresh market standards and to rapidly convert a higher proportion of the overall crop to stable forms. Additional basic information on the flavor components of peaches is needed to guide development of improved processed products from southern grown fruit.

Climatic conditions that cause rapid deterioration of fresh peaches both on and off the tree, erratic ripening periods and markets, and short-lived peach orchards are other factors contributing to the need for more extensively integrated fresh market-processing operations. Technical problems preventing the more rapid development of the peach processing industry in the Southeastern states must be overcome. Many of the peach varieties grown in the Southeast require a modification of processing procedures to make satisfactory standard products. Still other varieties cannot be used in these products, and new food forms must be found for them. Recent rapid advances in food science and processing technology make it possible through research to develop both new and improved peach products. These are needed to bolster the economics of the South's peach industry, as well as to provide the superior qualities and greater convenience that the consumer now demands in food products.

USDA AND COOPERATIVE PROGRAM

The research effort in this area has been terminated. It had been conducted under one contract designed to develop basic information on the flavor of peaches, particularly varieties grown in the Southeastern states (under Flavor).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 38.5 scientific man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Flavor

1. Basic Studies on Flavor and Aroma Constituents of Peaches. The Georgia Agricultural Experiment Station has completed its contract research on flavor and aroma constituents of peaches. Gas chromatography of acids isolated from three varieties of peaches at three stages of ripeness confirmed observations that malic and citric acids were major components, the latter predominant in

the shipping ripe stage, the former at the soft ripe stage. Nine ester components of peach flavor were identified by gas chromatography and infrared spectroscopy. (S3 2-44(C)).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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DECIDUOUS FRUIT AND TREE NUT UTILIZATION

Western Utilization Research and Development Division, ARS

Problem. Fruits and nuts are valued for their unique flavor, color, and mineral and vitamin content. In the period of abundance at harvest time, markets are glutted and growers often do not get an adequate return. Crops are perishable, and processing to preserve their unique qualities is difficult. No processed fruit retains completely the fresh values, although many highly acceptable products exist and about half of the fruits and nuts marketed in the United States are processed. Processing makes these commodities available to consumers the year around, and has opened new markets for producers. The proportion of processed commodities is steadily increasing but is dependent upon a continuing flow of new knowledge. Processing to preserve color, flavor, texture, and nutrients presents many problems, and each new product requires the application of much scientific and technological skill.

The continued supply of preserved fruits is largely dependent upon relatively inexpensive sources of raw material. Decreasing supply and increasing cost of harvest labor is leading rapidly to the development of mechanical harvesting methods. Mechanical harvesting does not allow the sorting and careful handling of traditional hand picking. The processor must deal with trash, and bruised, cracked, immature, and over-ripe fruit along with prime quality. Research is necessary to develop new processes and products to reduce costs and utilize such raw material in the processing plant.

The freezing process for preserving certain fruits keeps products at near fresh fruit condition, but many problems remain unsolved. The enzymatic browning of frozen peaches and the sloppy texture of frozen strawberries on thawing are two examples.

Frozen fruits require expensive low-temperature storage and transportation facilities. This expense can be greatly reduced by removing a portion of the water from the products. Orange and other fruit juice concentrates are well established in U.S. markets, and dehydrofrozen apple slices (rapid drying to 50% bulk weight and then freezing) are just becoming well established. Many other fruits and fruit juices should be amenable to concentration. Any frozen product, however, is not as well adapted for export as those which do not require refrigeration.

Maximum weight reduction, as well as less restrictive storage requirements, can be achieved through dehydration. The drying of fruit juices has been successfully accomplished by the vacuum puff drying and foam-mat drying processes. New methods are being developed to dehydrate pieces of fruit with excellent retention of color and flavor. Extension of laboratory procedures to pilot- and commercial-scale operations must still be done.

Flavor recovery and the incorporation of recovered flavor in solid carriers for addition to the dried products require technological and basic chemical

study. Aroma recovery techniques developed for fruit juice concentrates are being improved but require more work. Dried fruits are now widely used in the U.S. and abroad. Their popularity would grow if stable, higher moisture dried fruits were available and if lower levels of sulfur dioxide could be used without loss of quality.

Container costs for canned fruits limit the shipment of these products overseas. A solution of the container problem may be found in the use of lightweight fiber, foil, or plastic containers and aseptic filling procedures.

Fruit growers need new varieties of tree fruits and berries suited to processing and resistant to diseases endemic to each region of production. Utilization research is required in cooperation with farm research to assure growers of a market for fruit in the processing industry.

USDA AND COOPERATIVE PROGRAMS

In the Western Utilization Research and Development Division, a broad program of basic and applied research on deciduous fruits and tree nuts is conducted at the Division headquarters at Albany, California; in field stations at Pasadena, California, and Puyallup, Washington; by contracts in Berkeley, and Los Angeles, California, Fort Collins, Colorado, Geneva, New York, and Chicago, Illinois; and by grant funds under P.L. 480 in Israel, Taiwan, Austria, Switzerland, and India. Fundamental research is conducted on fruit constituents associated with flavor, color, and texture of fruit products. The work includes development of laboratory tools to isolate and characterize components, investigation of such components as they occur naturally and as they are altered by operations involved in preservation, and study of the relationships between the components and the product values being preserved. Applied research is conducted to develop new and improved processes and products that will increase utilization of fruits and tree nuts, including the development of high-quality concentrated and dehydrated products and more stable shelled tree nuts and the selection of improved processing varieties. Pioneering research on plant enzymes is also conducted.

The Federal program of research in this area totals 31.7 scientist man-years, including five contracts. Of the total number, 5.0 are assigned to investigations on chemical composition and physical properties; 7.5 on flavor; 2.0 on color, texture and other quality characteristics; 2.2 on microbiology and toxicology; and 15.0 on technology--process and product development. In addition, the Division sponsors research on fruit by means of six P.L. 480 grants.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 38.5 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties1. Novel Uses for Plant Enzymes in Processing and Maturation of Fruit.

We are conducting research in plant enzyme chemistry to obtain basic knowledge upon which to build entirely new or more advantageous ways to utilize plants and plant products.

We have demonstrated that localization of enzymic activity within plant cells is greatly influenced by age of the cell, temperature under which it is grown, and what it is fed. This work, done with plant tissue cultures, appears applicable to whole plants, and it indicates that we may be able to optimize desirable components of plant cells by appropriate choice of environmental conditions.

We found that glutaraldehyde alters enzyme activity, both in cells and in vitro. In the case of an acid phosphatase present in the nuclei of plant cells, glutaraldehyde activates this enzyme, both in the intact cell and in its isolated nucleus.

Life processes in plants, such as germination, growth, maturation, sex expression, flowering, reproduction, and senescence, are regulated by hormones. Many of these hormones, e.g., abscisins, gibberellins, and steroids, are synthesized by plants from isoprene units. The metabolism of radioactive kaurene, a precursor of gibberellins, was found to be altered under flower-inducing conditions in Japanese Morning Glory. Conversion of kaurene to steviol, a substance closely related to the gibberellins, was demonstrated in a shrub. Inhibitors of the biosynthesis of gibberellins stunt the growth of conifers.

The female sex hormone, estrone, was discovered in the seeds of date palm and pomegranate trees. Cholesterol, the starting material from which all steroids are synthesized in animals, was shown to have a similar function in plants. By administering radioactive cholesterol to growing plants, its conversion to pregnenolone (a progesterone precursor in both plants and animals), sapogenins, and two types of steroidal alkaloids (with 21 and 27 carbons) was demonstrated. New chromatographic techniques for steroids have been developed.

2. Rancidity Control in Walnuts. We have studied the chemical basis for rancidity development in nut meats. Cold-pressed oils obtained from fresh and rancid walnut kernels were stripped in a molecular still. Three fractions were obtained: odorless stripped oil containing glycerides and other non-volatile constituents, molecular distillate, and volatile components trapped at -60° C. Yields of molecular distillates and the intensities of rancid odors in the volatile fractions increased with the moisture content of kernels and time and temperature of storage. Odor of the volatile fraction obtained from fresh kernels was similar to that

of rancid kernels but of lower intensity, suggesting quantitative but not necessarily qualitative differences. The molecular distillate contained three groups of compounds: uncharacterized, highly polar compounds; free fatty acids; and fatty acid methyl esters. The last group of compounds has been individually characterized in natural oils for the first time. Unequivocal proof of their identities was obtained. Systematic analyses of oils obtained from moisture-adjusted kernels, stored for one year at various temperatures, showed that major changes occurred in the proportions of the three groups of compounds during storage. Variations among individual compounds within each group are being investigated.

B. Flavor

1. Improved Flavor of Apple Juice and Concentrate. We are conducting research to improve the flavor and flavor stability of apple juice and concentrates. WURVAC is a new process we have devised for recovering volatile flavors. Aroma components and some water vapor are removed from juices by boiling at reduced pressure. The mixture is condensed at low pressure and the aromas are separated from the water by vacuum stripping with an inert gas. Then aromas are reabsorbed into a cold, highly dispersed solvent at atmospheric pressure. Orange concentrates made with WURVAC aroma and peel oil added are more like fresh orange juice than those made by the cutback method and they are as stable.

Some fruit aroma volatiles, notably esters, can be removed from juices or concentrates by extraction with liquid carbon dioxide at room temperature and elevated pressures. A laboratory-scale extraction apparatus has been built and tested. Effectiveness of extraction increases from alcohols to aldehydes to ketones to esters, suggesting that anhydrous, alcohol-free flavor concentrate might be recovered without otherwise harming the juice.

We have identified fifty-six compounds in extract of commercial Delicious apple essence and have found that *n*-hexanal, 2-hexanal, and ethyl 2-methylbutyrate contribute significantly to aroma. Concentrations in 150-fold essence extract were 66, 295, and 4 ppm, respectively, but the first two compounds are not present in high concentration in fresh Delicious apple volatiles. Extraction efficiency of ether is most efficient, liquid carbon dioxide and charcoal are nearly as good, and the latter is excellent for extraction of alcohols. Fluorocarbon 114 and isopentane reject organoleptically unimportant low-molecular weight alcohols.

Supported by P.L. 480 funds, the Federal Research Station for Arboriculture, Viticulture and Horticulture in Wädenswil, Switzerland is studying enzyme systems and substrates and their effects on flavor and aroma of apple juice concentrate. Preliminary experiments on the influence of pectolytic enzymes on apple juice volatiles are underway. Volatiles from stored apples have been absorbed on activated carbon to study composition of emanations during preclimacteric and postclimacteric stages of maturation.

2. Improved Flavor of Canned Ripe Olives. Research aimed at controlling the development of off-flavors in the processing and storing of ripe olives for canning is being conducted by contract with the National Cannery Association's Western Laboratory in Berkeley, California. An expert taste panel from the olive industry could not agree on terms to describe various off-flavors in canned ripe olives. They could distinguish off-flavored samples from controls, but agreed descriptively only on metallic or bitter off-flavors. Olives held in brine for 20 to 30 weeks were judged superior to those stored for 15 or 40 weeks. Gas chromatograms of vapor from Mission, Manzanillo and Sevillano varieties were distinctly different, but differences could not be correlated with flavor. The pattern of change with time in volatile carbonyl compounds was determined. The content of polyunsaturated free fatty acids in raw olives decreased, but triglyceride-bound fatty acids changed little with brine storage of olives up to 40 weeks prior to lye-curing and canning.

C. Color, Texture and Other Quality Factors

1. Improved Stability of Apple Juice and Concentrate. The Colorado State University in Fort Collins is conducting contract research to eliminate cloud and sediment from apple juice. Sediment from clarified apple juice is a heterogeneous mixture relatively high in sodium. Bulk of the sediment is a polymer (molecular weight over 50,000) of protein-oxidized leucoanthocyanidin. Oxidation of leucoanthocyanidin may be minimized by treatment with salt and ascorbic acid during milling. Oxidized leucoanthocyanidin may be removed by filtration with polyamides prior to bottling. Plant runs have verified laboratory findings.

2. Improved Color and Stability of Fruit Products. We have initiated a study of the oxidative and light-catalyzed changes occurring in carotenoid pigments, and the oxidative, condensation, and complexing reactions of anthocyanins of fruits, to develop means for improving and stabilizing the color of fruit products.

We have completed a study of changes these anthocyanins and carotenoid pigments undergo during processing. Many flavylum salts decolorize in aqueous solution at pH 3-4 by reversible hydrolytic opening of the pyrylium ring to form chalcones. In fact, at pH 4-7 these flavylum salts exist largely (80-90%) in the form of those hitherto unsuspected chalcones. From these studies, the mechanism of sulfite bleaching of anthocyanins (a process of commercial importance, e.g., in the preparation of maraschino cherries) has been unraveled. The anthocyanin carbonium ion and bisulfite ion react to form a colored chromen-2-sulfonic acid. It may be possible to use certain synthetic flavylum salts closely related structurally to natural fruit pigments as yellow and orange colored substitutes for potentially carcinogenic azo dyes formerly used in food products.

We have shown that oxidation of flavylum salts at pH 5-7 actually yields phenolic 2-phenylbenzofurans. This discovery also has important applications

in fields unrelated to anthocyanin chemistry. 2-Phenylbenzofurans are physiologically active compounds with potency as great as that of vitamin E in preventing hemolysis of red blood cells by dialuric acid. We have prepared these compounds by simple oxidation of flavylum salts.

Coumestrol, the complex coumarino-benzofuran from alfalfa, is a potent estrogen responsible for infertility problems in cattle and sheep. Coumestrol and related compounds have now been synthesized by oxidation of 7,2',4'-trihydroxy-3-methoxy-flavylum chloride. The oxidation of flavylum salts to coumestrol and other 2-phenylbenzofurans requires the presence of alcohol. In its absence a new type of oxidation product is formed; the structures of these new products have been determined.

Flavylum salts rapidly condensed with phloroglucinol, resorcinol, and catechin (the most widespread natural polyphenol) to form crystalline dimers, the structure of which has been elucidated. This reaction is of great importance in suggesting one possible mechanism whereby dimeric flavonoids and tannins may be formed in plants. The surprising observation was also made during these condensation reactions, that considerable reduction of flavylum salts to colorless flavones occurs. Similar reduction of anthocyanin pigments, by reaction with co-occurring phenols, may thus be an important factor in anthocyanin decolorization,

Flavylum salts form colorless condensation products with reactive methylene compounds. Surprisingly, we found that certain flavylum salts form different products depending on the pH of the reaction mixture.

The reduction of a number of model flavylum salts with sodium borohydride, and with zinc and acid, has now been studied. Crystalline monomeric flav-2-enes are formed, as well as crystalline dimers. The structures of these dimers are complex and have not yet been elucidated.

The University of California at Los Angeles is conducting contract research on leucoanthocyanins and related phenolic pigments in fruits and their fate during processing. The work under this contract has led to the proposal of the structure of a naturally occurring proanthocyanidin and to proposals for a structural model for the condensed flavonoid tannins. Synthetic models have been prepared, the nature of which reinforce the belief that the hypotheses are sound. It is still necessary, however, to refine the evidence and to continue to study natural and synthetic proanthocyanidins. The materials studied up to this time have seldom been crystalline or homogeneous, probably because of stereochemical differences. Therefore, efforts are being made to prepare homogeneous, preferably crystalline compounds of the dimeric proanthocyanidin class in order to obtain further physical evidence for their structures.

Supported by P.L. 480 funds, the National Taiwan University in China is conducting a study of hemicelluloses and associated nitrogenous compounds. Hemicellulose plays a dominant role in the texture of bamboo shoots. Two

polysaccharides, a glucoxytan and an arabogalactan, appear to occupy the position in the cell wall architecture usually held by pectin. Carbohydrate analysis indicates that polysaccharides are synthesized from glucose in two ways: an independent reaction whereby glucose transfer yields cellulose, and a xylose transfer-dependent glucose transfer that yields glucoxytan. Different precursors are involved. ^{14}C -labeled and non-labeled sugar nucleotides are being synthesized by enzymic and organic syntheses.

P.L. 480 funds are also supporting research at the University of Delhi in India where a study of the chemical behavior of leucoanthocyanins in fruits is underway. Condensed leucoanthocyanidins were isolated from white grape seeds. A proanthocyanidin was recovered from the white grape peels. Only condensed leucoanthocyanidins were found in ripe fruits. Leucoanthocyanidins were recovered from apple juice and (in small quantities) from pears. As pears ripen, polymeric leucoanthocyanidins increase. Unripe fruits have lower polymers; the astringency of these fruits may be due to greater solubility of these substances.

Tannins and related polyphenolic polymers are responsible for the astringent flavor and cloud formation in clear juices. Existing methods for degrading these substances are drastic chemical procedures with undesirable side reactions. The Central Leather Research Institute in Madras, India, supported by P.L. 480 funds, is studying microbial and enzymic methods of degradation which might replace existing methods. The banana and cashew apple are under investigation. During ripening the free tannin content of bananas decreases. A comprehensive screening program was initiated to investigate the ability of microorganisms and plant enzymes to degrade tannins and other natural and synthetic polyphenols.

Supported by P.L. 480 funds, the Hebrew University in Jerusalem, Israel, is studying the nature, activity, and distribution of phenolases in deciduous fruits in order to minimize enzymic browning of products. Content of o-diphenyls and catechol oxidase activity were studied during apple development from fruit set to harvest. Content of o-diphenyls peaked early in development and then declined. Catechol oxidase activity peaked after that of the o-diphenyls. As fruit ripened, activity dropped sharply in particulate fractions. Browning rate in apple slices decreases with lowered enzyme activity. Sodium chloride inhibited activity in enzyme apple mitochondria. Increasing the sodium chloride concentration increased the inhibition. When the sodium chloride was removed by dialysis, the activity increased.

D. Microbiology and Toxicology

1. Control of Microbial Contaminants in Dried Fruits and Tree Nuts. We are conducting research to determine the sources of microbial contamination of concentrated fruit juices and methods for control. Heat-resistant molds were isolated from grapes and adjacent produce in the San Joaquin

Valley. Byssochlamys fulva exhibited the greatest heat resistance. Addition of 100 ppm. of sulfur dioxide reduced the heat resistance by 50% and precoat filtration reduced the asci and ascospore count by more than 99%.

Propyl p-hydroxybenzoate is an effective antimycotic agent for use on dates. Heat-treated raisin paste stored 6 months developed no objectionable off-flavor. A feasibility study indicates that some defective prunes can be sorted out electronically. Prune skins can be tenderized by combined heat and chemical treatments. Light colored, sulfur-free raisins have been produced by blanching Thompson seedless grapes before drying. Good flavored almond-fruit pastes with excellent texture have been prepared. If figs are refrigerated before grinding, a lighter colored fig paste results.

With P.L. 480 funds, the Institute of Biology and Agriculture in Vienna, Austria, is conducting research to discover physical or chemical methods of increasing irradiation sensitivity of yeasts and molds to reduce heat requirement for fruit juice pasteurization. They have found that conidiospores from different strains of Byssochlamys fulva differ markedly in resistance to irradiation. Ultrasonic treatment was better than other chemical and physical treatments to initiate spore germination in B. fulva. They have also found indications that magnesium ion is involved in spore germination.

E. Technology--Process and Product Development

1. Improved Wine and Juice Concentrates from Viniferous Grapes. Thompson seedless grapes, used for raisins, fresh fruit, and as a blending juice for wines, have been a surplus crop for a number of years. Methods for extracting a sediment-free juice would be useful for a number of new products, such as foam-mat dried powder and bland syrups. Improved extraction of flavor and color from red varieties of grapes would complement the work on white varieties in order to enhance the usefulness of possible blends. Thompson juice concentrates which have received insufficient heating in processing have been reported to contain the highly thermal stable mold organism, Byssochlamys fulva. Cooperative studies with the National Canners Laboratories have been conducted to determine optimum heating conditions and combined heating and chemical treatments for control.

We are conducting research to develop products from Thompson seedless and other viniferous grape varieties to increase markets. Verjuice, a potential blending acidulant, was prepared from unripe Thompson seedless grapes and preserved with diethylpyrocarbonate (DEPC). Harvesting of immature clusters will have the cultural effect of pruning. Peeled grapes can be dried osmotically against sugar or a hypertonic solution when an edible membrane is cast on the fruit. They rehydrate easily. Compounds isolated from Grenache grapes and identified included 1-hexanol, 3-methyl-1-butanol, trans-2-hexanal, hexanal and 1-heptanol. Mold infestation of cold storage rooms can be eliminated by spraying with DEPC. Waste processing waters

can be purified by passage over activated carbon and the chemical values returned to stream, thus effecting monetary savings and avoiding pollution.

Research aimed at improving the color and flavor of beverage juices from surplus viniferous grapes is underway. A rotating-drum countercurrent liquid-liquid extractor for emulsion-free extraction of wine components has been constructed. Wines directly fermented to high alcohol content were aged, after addition of fungal extracts, in straight and charred wood. With the latter, bourbon-type flavor developed in the wine. Growth of Aspergillus niger increases acidity of musts without a "musty" flavor if conidia growth is repressed. Electrolytic regeneration of ion exchangers for winery use shows substantial production savings and reduction of pollution. The method has been demonstrated to the industry. Biochemistry of Botrytis cinerea and its extracted enzyme systems was studied and new cultural methods investigated.

The mechanism of air oxidation of catechols and resorcinols to yield benzofurans appears similar to polymerization of polyphenols and tannins in grapes and wines. Two new bioflavones (hinokiflavone methyl ethers) have been isolated and identified from the leaves of Cryptomeria japonica.

Investigations are conducted under contract at the New York Agricultural Experiment Station in Geneva to develop better methods and materials for eliminating haze and precipitates in domestic wines so that they can compete in world markets. Protein-tannin complexes are held together by hydrogen bonding. The formation of the insoluble complexes is reversible and dependent on the ratio of tannin to protein in the mixture. The process can be reversed by adding a competing but non-precipitating simple phenolic compound and by heat. The size of insoluble particles can be kept small by adding tannin to gelatin solutions. More dilute solutions produce less precipitate. Water takes part in the reaction, as indicated by the effect of alcohol on tannin content of the precipitate. Loss of anthocyanin in tannin-protein systems is reduced by high tannin levels, indicating that competition for available sites on the protein exists between tannins and anthocyanins.

Contract research on the processing of viniferous grapes at the University of California in Davis has been concluded. A pilot scale "serpentine" press was developed for the continuous separation of juice from crushed white grapes. From tests with the prototype press, a commercial model has been built which should yield 150 gallons of juice per ton of Thompson seedless grapes.

A 3-stage countercurrent sugar extraction system was constructed and tested on a laboratory and commercial scale. The commercial unit, operated at 30 to 50 tons per hour on fermented and unfermented pomace, gave yields of 70 to 80% of theoretical equilibrium. Highest performance was achieved when the pomace was disintegrated.

Experiments on extraction of color of red grapes resulted in the development of a system for heating the grapes for short periods of time under 25 and 40 psig steam pressure. Various parameters, such as time, temperature, extent of fermentation, and aging were studied and optimum conditions were ascertained for different types of wine from numerous grape varieties. The extraction and identification of aroma materials from viniferous grapes were studied. Methods for flash steam heating gave results comparable to control samples. Eight Muscat-flavored grapes were analyzed by gas chromatography and the differences in types and quantities of volatile compounds were compared with the subjective evaluations of aroma.

2. Osmotic Concentration of Fruit Juices. Research is conducted to develop a method to dehydrate piece-form fruit having good flavor, color, stability, and other quality factors to increase markets. Excellent dehydrofrozen fruits were produced by osmotic dehydration in syrup to 50% weight reduction followed by freezing. Rehydration of these products was slow, but was much improved by cycling the fruit between boiling and cold water baths two or three times. Osmotically dehydrofrozen fruits can be further dehydrated at any time with no loss in quality.

Fourteen batches of Bartlett pears were osmotically dehydrated in succession in one lot of syrup. The syrup darkened slightly, but the pear color remained light. Syrup could be used indefinitely in this system since about 1/7 of the syrup was lost with each batch and made up with fresh syrup.

Sucrose and lactose inhibited polyphenol oxidase activity about 40% at 1 molar concentration. Other di- and tri-saccharides were ineffective, as were glycerol and ammonium sulfate. Monosaccharides were only half as effective as sucrose. Therefore, the inhibition is relatively specific and is not due to osmotic pressure alone.

In studies of moisture determination methods, raw fruit or powdered dried fruit was pressed into thin films, which greatly increased the rate of dehydration, but the last traces of moisture were difficult to remove. Addition of methyl alcohol as a water extractant showed promise, but the alcohol evidently replaced water in dried fruit since according to Karl Fischer titration, moisture content was reduced to zero but no equivalent weight loss occurred.

3. Evaluation of Processing Characteristics of Northwest Soft Fruit and Berries. We are cooperating with industry and state research horticulturists in the introduction of improved varieties of Northwest soft fruits and berries. Improved cultural practices and preservation methods are under study. Evaluation of raspberry hybrids led to the introduction of Meeker, a high yielding, new variety that tolerates freezing very well. It has good red color and fine flavor, but large seeds. Over half of the 46 strawberry and 84 raspberry hybrid selections evaluated as frozen fruit have been eliminated because they were of poor quality

when processed. Strawberries, raspberries, cherries and sliced Elberta peaches frozen by immersion in Freon 12 had better texture than air-blast frozen fruit. Texture of Freon-frozen peach slices after thawing in syrup was similar to fresh peach texture. Thawed slices stored at 35° F. in syrup containing 1% ascorbic acid and 0.1% potassium sorbate retained good eating quality for 2 months. Drained weight of canned blueberries, as well as the viscosity and pectin content of the syrup in which they were packed, were influenced by harvest intervals.

4. Fluidized-bed Freeze Drying of Fruit and Fruit Powders. Malecki Laboratories, Inc., Chicago, Illinois, is conducting contract research to develop a continuous fluidized-bed freeze dryer for making fruit juice powders. The apparatus has been erected. Fruit juice is sprayed into the chamber by a rotating disk. A stream of liquid nitrogen enters through a perforated ring around the top of the chamber and runs down the walls of the chamber to cool it. A thin section collects the frozen droplets and acts as a fluidized bed, once sufficient droplets have collected. Air can be admitted into the bottom of this thinner section to fluidize the particles lying above. The apparatus will have low capacity but will demonstrate process principles.

5. Dried Fruit and Dried Fruit Products. Research is conducted to develop new products and improved processes to increase markets for dried fruits. Air-packed and nitrogen-packed Winesap applesauce flakes with good initial quality remained nearly unchanged in flavor after one year at room temperature, but color darkened slightly in the air-packed sample. Samples with marginal initial quality needed the protection of nitrogen packing. Can fill weight (bulk density) was doubled by hot-rolling dried applesauce flakes into a dense sheet and regrinding it into granules which still reconstitute instantly. Instant applesauce is about 33% cheaper to produce by drum drying than by the process that starts with evaporated apples, and the densified drum dried instant applesauce meets military specifications.

6. Process Modification to Reduce or Find Uses for Food Processing Wastes. To help minimize pollution of land, waters and atmosphere from sources associated with food processing, we have initiated exploratory studies on disposal or reclaiming of food processing wastes.

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VEGETABLE UTILIZATION

Eastern Utilization Research and Development Division, ARS

Problem. Vegetable growing occupies over 3 million acres, with a yearly farm value of a billion dollars. Utilization as processed rather than fresh vegetables provides a constant source of supply with less price fluctuation. Basic compositional research is needed to provide knowledge to constituents responsible for color, flavor and texture of vegetables and the changes these constituents undergo during processing, storage, and distribution. There is also need for application of these results to developmental research on new products and new and improved processing technology. Consumer preference is shifting to "convenience" foods. An even greater emphasis on quickly prepared foods is evident in modern military feeding where high bulk density, non-refrigerated, and rapidly rehydrating products are of primary importance.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program employing chemists and chemical engineers in basic and applied research on vegetable processing and products. The Federal work is conducted at Wyndmoor, Pennsylvania. The scientific effort assigned to this area totals 3.5 scientist man-years and is currently engaged in research on technology-process and product development.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 28.7 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Technology - Process and Product Development

1. Quick-cooking dehydrated vegetable pieces. Carrot dice have been successfully prepared in the continuous explosion-puffing pilot plant. The output of carrot pieces at about 25% moisture content has reached 1000 pounds per hour. At a moisture level of 23% an output rate of 935 pounds per hour was achieved. The 23% moisture content dice is a better product because it is free-flowing and nonsticky. California celery in one-half-inch slices, water blanched in alkaline solution (pH 8.2 - 8.6), dried to 35% moisture and puffed at 40 pounds per square inch gave a product of excellent color and texture. The dice rehydrated satisfactorily in four minutes, the color of the product is good, and the flavor satisfactory.

2. Dehydrated mushroom products. The through-circulation drying of dice and slices of cultivated Agaricus campestris mushrooms (recently termed Agaricus bisporus) yielded good results if the mushrooms were very fresh, if they were of the white variety and if low temperatures (90°F. or lower) were used either throughout the whole drying cycle or initially followed by drying at a higher temperature. The air-dried mushrooms lose initial flavor in approximately one to two months if the moisture content is 10% or higher. If dried to 6.5%

moisture they retain flavor at least six months. These studies suggest that it should be possible to make a good dried product in particulate form by controlled hot-air drying and that such a product should help growers meet competition from Taiwan.

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Technology -- Process and Product Development

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VEGETABLE UTILIZATION

Southern Utilization Research and Development Division, ARS

Problem. Although extensive progress has been made in recent years in developing stable, attractive, and convenient vegetable products, new and improved processed products must be developed and means of stabilizing perishable vegetables provided to minimize the adverse effects of seasonal surpluses and unfavorable markets and to provide an adequate supply of good food for a growing population. Product quality needs to be improved and processing costs reduced through the adaptation and application of the latest technological developments and nutritional findings. For example, a major problem of the cucumber industry, since most of the crop is brine-cured, is to improve the curing process so that no loss occurs in the value of the cucumber during brine curing and storage. Thus the cost of processing would also be reduced. New pure culture fermented products are needed to more fully utilize cucumbers and many other vegetables in attractive consumer items. Celery, already an important flavoring ingredient, could become much more important if the factors and constituents responsible for the intensity, variability, and stability of its flavor could be controlled in processing, and more flavorful and convenient products could be developed. A precooked, dehydrated, sweetpotato product that usually has good shelf life when sealed under an inert gas has been developed. It reconstitutes to a product having the characteristics of freshly cooked and pureed sweetpotatoes. However, applied research on a pilot-plant scale is needed to obtain additional engineering and processing data applicable to commercial production of flakes from sweetpotatoes of different variety and environmental history. Research is also needed to further improve quality and storageability of the product, particularly if packaged in air, and to provide the scientific basis for the development of a process for making excellent flakes from uncured, freshly dug sweetpotatoes. Another area that should be investigated is the possibility of developing new food products in which sweetpotatoes are combined with other foods.

To improve processed vegetables, there is a continuing need to investigate the characteristics of the raw material as they are affected by climate, soil, cultural practices, and breeding. Several vegetable crops, including sweetpotatoes, hot peppers, okra, and Southern peas, are grown almost exclusively in the Southern Region. Many other vegetables grown in warm climates differ in their chemical and physical characteristics from the same crops grown in the temperate regions. Tomatoes, for example, are frequently poorer in color, flavor, and texture. More utilization research is needed to complement the Federal and State production research programs and to provide cooperation in the form of composition and processing studies. This kind of cooperation is also needed to prevent the release of breeding selections that are entirely unsuited for processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, microbiologists, food technologists, and chemical engineers engaged in both basic and applied utilization research studies on vegetables of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of vegetables, their products, and their byproducts is conducted as a basis for efficient research in developing new and improved food products and processing technology. Research conducted at and in cooperation with the North Carolina Agricultural Experiment Station, Raleigh, North Carolina, is concerned with basic investigations of the chemistry and biochemistry of the carotenoid pigments in vegetables in relation to variety, maturity, and environmental factors, to facilitate the development of improved and more attractive processed products. Additional research on chemical composition and physical properties is being carried out under a grant at the Research Triangle Institute, Durham, North Carolina, on elucidation of the molecular structure and chemical characteristics of the pectinase inhibitor that occurs in sericea forage and other plant sources and has proved effective in preventing softening of cucumbers in brine curing.

Investigations of factors influencing the flavor of fresh, acidified, and fermented vegetable products, with emphasis on cucumbers, are being carried out at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina, to provide the basis for increasing consumer acceptability. The North Carolina and Michigan Agricultural Experiment Station and the Pickle Packers International, Inc., cooperate in this research.

In the development of technology for new and improved processes and products, both basic and applied research is being carried out at New Orleans, Louisiana. Research is being conducted on the use of sweetpotatoes in combination with other foods to produce new products, the incorporation of protein concentrates and other nutrients, and investigation of constituent changes produced by the enzyme α -amylase. Pilot-plant investigations are being conducted as a phase of this research. Cooperation is maintained with the Marketing Economic Division, ERS, for the market evaluation of improved products, and with the Louisiana Agricultural Experiment Station, the Louisiana Sweetpotato Association, the Louisiana Sweetpotato Commission, the North Carolina Yam Association, North Carolina State College, the Sweetpotato Council of the United States, and other associations and industry groups. Other research on process and product development is in progress at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina. Current emphasis is on investigations of methods for the controlled fermentation of cucumbers and other vegetables by application of pure culture techniques to fermentation practices to reduce processing costs and improve product characteristics. Limited cooperative work is conducted to evaluate new

cucumber varieties (or selections) for processing into brine-cured and fresh-pack products. Cooperation is maintained with the North Carolina Agricultural Experiment Station. The Michigan State University (Department of Microbiology) is also cooperating by providing technical assistance in the controlled fermentation studies. The Pickle Packers International, Inc., also provides technical assistance and supplies raw material. The U. S. Food Crops Utilization Research Laboratory, Weslaco, Texas, is conducting research directed toward developing new and improved processed products from Southern-grown vegetables other than sweetpotatoes and celery. The Texas Agricultural Experiment Station, the Crops Research Division, ARS, and industry associations provide raw materials of known history for this research. In progress at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, is research on the development of an improved natural celery flavor from essential oil of fresh celery to expand and improve the use of this vegetable.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 8.1 scientific man-years. Of this total, 2.2 is devoted to chemical composition and physical properties, 1.3 to flavor, and 4.6 to technology -- process and product development. The domestic grant research involves an additional 0.6 man-year, on chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 28.7 scientific man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Investigations of the Chemistry and Biochemistry of the Carotenoid Pigments in Vegetables. Research on the chemistry of carotenoid pigments in vegetables is continuing in cooperation with the North Carolina Agricultural Experiment Station. Geranylgeraniol--reported to be the final precursor for C₄₀ carotenes--has been synthesized for the first time in a -2-¹⁴C-labeled form. The availability of labeled geranylgeraniol and the results of its incorporation into plastids indicates that more efficient cell-free systems might be developed in which it may be possible to study carotenogenesis in greater detail. The pigmented carotenoids are of economic interest because all enhance the color of food processed from carrots, sweetpotatoes, colored grapefruit, peppers, and tomatoes; some have provitamin A activity; and some may be responsible for flavor deterioration in dehydrated products. Research on the latter characteristic has shown that in dehydrated high carotenoid food products off-flavor increases as carotene concentration decreases and thus may be caused by decomposition of products of the carotene. Chromatographically isolated fractions of a nonsaponifiable extract of Goldrush sweetpotatoes, presumed to contain precursors of off-flavor, were stored and then compared with the odor of good quality and

off-flavored sweetpotato flakes. Of these fractions, the one associated with carotene epoxide was judged to be most similar to the off-flavored flakes. (S3 5-28).

2. Identification and Characterization of Inhibitor of Enzyme That Softens Cucumbers. In a grant to the Research Triangle Institute, research is being conducted on the pectinase inhibitor extracted from the leaves of sericea forage and previously identified as a polymeric pro-anthocyanidin based on delphinidin, which is produced by acid hydrolysis of sericin. This information is important in understanding its use in the control of enzymatic softening of brined cucumbers. Elemental analyses have not yet permitted a clear-cut empirical formula for sericin to be derived. However, additional information on the inhibitor structure is being obtained from its reactions with periodate, benzoquinone, sulfurous acid, and other compounds. Another recent achievement is the development of a dialysis purification procedure that is more efficient with respect to savings in time and recovery of active enzyme inhibitor constituents than was the countercurrent distribution previously used. (S3 5-24(Gr.)).

B. Flavor

1. Factors Affecting the Flavor and Aroma of Cucumbers and Fermented Cucumber Products. Basic studies conducted in cooperation with the Pickle Packers International, Inc., and the North Carolina and Michigan Agricultural Experiment Stations have led to evidence that process conditions of cucumbers prior to fermentation may affect the flavor of the fermented product. Direct evidence has been obtained to support the theory that the aldehyde largely responsible for fresh cucumber flavor is not present in appreciable amounts in whole cucumbers but is formed enzymatically upon cutting or crushing the fruit. Thus it may be possible to control the formation of the green, or fresh, cucumber flavor in pickle products by proper timing and handling of the slicing and blanching operations. In another phase of the research, head-space vapor analyses of fermented vegetables have been extended. The technique has revealed that the highly volatile components of pure culture fermented cucumbers and olives are qualitatively very similar. Monitoring the odor of gas chromatograph effluents and retention data for methyl sulfide indicates that this compound is of major significance in relation to the flavor of fermented whole cucumbers and green olives. (S3 5-29).

C. Technology--Process and Product Development

1. Investigations to Improve Quality and Lower Costs of Processed Cucumbers and Other Vegetable Products. The pure culture fermentation process developed for cucumbers and other vegetables has been successfully applied to green olives. Although additional developmental work is required for commercialization, the process offers promise of controlling serious spoilage losses in brined olives caused by gassy deterioration, butyric fermentation, and enzymatic softening. A dividend has also resulted from the study of pure

culture fermentation of olives: a single lactic acid culture of Lactobacillus plantarum that has far more longevity, salt tolerance, acid tolerance, and regeneration power than any obtained from pickle brines. It promises to be extremely useful for the inoculation of pure culture pickle fermentations. It has also been established that Manzanillo olives and four other varieties contain a bacteriostatic material that has a selective inhibitory action for lactic acid bacteria according to species, with L. plantarum being the most resistant of those tested. Discovery of this bacteriostatic substance could lead to a completely new approach to the control of fermentation processes in vegetables. This research is conducted in cooperation with the Pickle Packers International, Inc., and the Michigan and North Carolina Agricultural Experiment Stations. (S3 5-27).

Experiments conducted in cooperation with the Texas Agricultural Experiment Station to confirm and extend earlier observations from a previous project have shown that the application of calcium chloride at the early stages of processing, such as peeling, offers advantages in firming canned whole tomato products and in increasing the viscosity of canned tomato juice; this is an improvement over other procedures in use, which involve additives. However, a machine for peeling tomatoes in the solution should submerge them for a specifically selected period of time. Otherwise, the epidermal cells are cooked and the effectiveness of the firming treatment is reduced. This increased time in solution may account for the fact that the treatment was not as effective for the Chico variety as it previously had been for Chico Grande. (S3 5-30).

2. New and Improved Dehydrated Sweetpotato Products and Processes.

Knowledge of the characteristics of α -amylase and means for controlling its activity have made it possible to make uniform and acceptable flakes from Goldrush having varied histories, including freshly harvested sweetpotatoes, stored and freshly cured roots, and cured and stored roots. Activating the enzymes in uncured sweetpotatoes in piece form, rather than as a puree, produces a greatly improved flake product. Studies on the effect of processing variables and changes in the raw sweetpotato roots during storage have shown that α -amylase content, conversion temperature, and conversion time influence the sugar content of the flakes. The principal change during processing was the conversion of starch to maltose. Indications are that low solids concentrates of the α -amylolytic fraction in sweetpotatoes could be prepared in quantity, an achievement that may lead to a method for controlling and improving the characteristics of the flakes. (S3 5-31).

3. Development of Processed Celery Products of Improved Flavor and Convenience.

Swirling agitation was found to be the only method of successfully rehydrating conventionally dried celery and was also the best method for celery treated to promote rapid rehydration. The length of time required for good rehydration is still too long to be practicable for use in prepared consumer products. However, a distillation process for recovering oil from celery waste was developed, and future work will be confined to development of a better essential oil from fresh celery. (S3 5-23(Rev.)).

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VEGETABLE UTILIZATION

Western Utilization Research and Development Division, ARS

Problem. Vegetable crops, in general, are perishable and seasonal and thus are subject to supply and price fluctuations to the disadvantage of the agricultural economy. In order to expand markets and stabilize prices, new and improved processed products are needed that will be desirable to the domestic and foreign consumer from the standpoint of quality, convenience, stability, nutritive value, safety, and cost. The quality of processed vegetables and the economy of their processing have not improved rapidly enough to increase or even maintain the relative position of vegetables in the American diet, or to increase substantially their contribution to the export trade. The consumption of dry beans and certain other vegetables is limited by the fact that they cause flatulence.

New easy-to-prepare vegetable products are needed, particularly from such commodities as dry beans and peas, which now require hours to prepare. The severe heating required to sterilize low-acid foods, which include most vegetables, seriously impairs the quality of canned products. The stability of all kinds of processed vegetables needs to be improved so that quality and nutritive value will be better preserved during storage and distribution. The safety and effectiveness of new chemical additives, needed to improve the quality and stability of processed vegetables, must be established. Processing operations need to be modified to cope with special problems arising from the trend toward mechanical harvesting of many vegetables. Better methods of removing residues of agricultural chemicals from vegetables for processing are urgently needed, as are procedures for decontaminating vegetables exposed to radioactive fallout. Of vital importance is research to reduce the costs of processing in order that the farmer may receive a larger share of the consumer's dollar.

Applied research on these practical problems must be supported by a strong program of basic research on the chemical constituents of vegetables responsible for flavor, color, and texture; on the reactions these compounds undergo before, during, and after processing; on constituents having biological activity; on the microscopic structure of vegetables and vegetable products; and on the micro-organisms which cause spoilage or loss of quality in these products.

USDA AND COOPERATIVE PROGRAMS

In the Western Utilization Research and Development Division, a broad program of basic research on vegetables and the application of science to new and improved products and processes is conducted at the Division headquarters at Albany, California, in field stations at Pasadena, California and Puyallup, Washington; by contracts and grants at Urbana, Illinois, East Lansing, Michigan, and Davis and Berkeley, California; and by grants under P.L. 480 in Finland, India, and France. Fundamental studies are

conducted on the chemistry of vegetable flavors and vegetable pigments, the mechanism of heat resistance in bacterial spores, the composition of dry beans as related to cooking quality and flatulence-producing characteristics, the factors affecting deterioration of dehydrated vegetables, and the microbiology of raw vegetables for processing. Applied research is conducted to develop new and improved products including high-quality concentrated and dehydrated products and products of improved convenience; to improve processing methods, including freezing; to evaluate new processing varieties; and to develop methods for removing radioactive fallout.

The Federal program of research in this area totals 30.4 scientist man-years, including five contracts and grants. Of the total, 3.5 are assigned to investigations on flavor; 2.9 on color, texture and other quality characteristics; 5.6 on microbiology and toxicology; and 18.4 on technology--process and product development. In addition, the Division sponsors three grants under Public Law 480 on basic research.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 28.7 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Protein Components of Dry Beans. P.L. 480 funds are supporting research at the Allahabad University in India to identify components and factors contributing to the overall biological value of dry beans. Phaseolus mungo, P. aconitifolius, three varieties of P. vulgaris, and five inedible, uncultivated legume seeds were studied. Each variety of seed had its own amino acid pattern, and none was complete in respect to the essential amino acids. Two acacia varieties contained an unidentified sulfur-containing amino compound. About 60% of the total nitrogen of Phaseolus seeds was in a globulin protein. All the amino acids essential for animal nutrition were found in the globulin of one vulgaris variety. Two vulgaris varieties and the mungo and aconitifolius varieties were deficient in tyrosine and tryptophane. In the latter two, methionine was absent.

B. Flavor

1. Dehydrated Vegetables of Improved Flavor. We have concluded a study of the flavor precursors and corresponding enzyme systems which produce flavors in certain vegetables, including onions, peas, and cabbage.

Studies were conducted on the problem of bitterness in onions. Apparently when onions are sliced, no bitterness develops on standing. However, if they are comminuted into fine particles and the juice expressed, a bitterness develops in the juice. A similar phenomenon is observed if onion slices are frozen and allowed to thaw. The reaction is, in part,

enzymatic since immediate heating of the onion juice or acidification to pH 3, followed by adjustment of the pH back to the normal pH of onions, prevents the development of bitterness.

Preliminary investigations of this reaction have shown that trans 1-propenyl-2-cysteine sulfoxide (the natural precursor of flavor in onion) will produce bitterness when treated with onion enzyme. Methyl, propyl, or allyl cysteine sulfoxides yield strong odors when treated with onion enzyme, but no bitterness. The cause of formation of bitterness in finely disintegrated or crushed onion, but not in slices, is still obscure. The problem is of practical importance for those who may wish to market an onion juice or frozen slices. The bitter material has been isolated from onions as a relatively non-volatile oil consisting of sulfur-containing compounds. Chromatography has separated the oil into five distinct fractions or sulfur-containing compounds, four of which are intensely bitter and possess a definite onion flavor. It is believed that previous studies of the volatiles of onion have revealed only a part of the overall flavor pattern since the new, as yet unidentified components are in some respects more reminiscent of onion taste, in spite of their bitterness, than the volatile disulfides previously isolated. The new compounds are not disulfides but probably contain oxygen in addition to sulfur. This suggests such structures as linear or cyclic thiolsulfinates or thiolsulfonates.

It has been observed that addition of cysteine in very small amounts to food products prepared from onion and other species of the genus Allium, results in a 10- to 40-fold increase in odor intensity and in the alteration of aromagrams of the volatiles. This may find application as a food additive or flavor potentiator when applied in very small quantities.

New ninhydrin-active components have been isolated from cabbage extracts by means of ion exchange chromatography. It has not been determined whether the compounds are single amino acids or peptides, but they appear to be different from anything previously isolated.

In studying flavor compounds, mass spectrometry is providing a powerful tool for identification of individual components. However, in interpreting mass spectra we need to know how various molecules are fragmented in a mass spectrometer. To learn this, known compounds are synthesized so that their fragmentation patterns can provide insight and comparison with the patterns of unknown substances. A series of 44 aliphatic thiol esters has been prepared and purified by distillation and gas chromatography. The thiol esters $R'-C(=O)-SR''$ covered a wide range of molecular weights with R' varying from C_2 to C_8 and R'' varying from C_1 to C_{13} , including branched chains. These compounds have been examined in the mass spectrometer and their breakdown patterns established. Thiol esters are believed to be present in fruits and vegetables and knowledge of their breakdown patterns should assist in their identification.

P.L. 480 funds are supporting research by Nobel laureate A. I. Virtanen at the Biochemical Institute in Helsinki, Finland, to identify minor organic components of plants that may function as precursors of enzymic or chemical reaction products which affect flavor. A new γ -glutamyl-tripeptide containing both a reduced and an oxidized sulfur has been isolated from chive. Studies of cycloallin suggest that 2-hydroxyl-propyl cysteine is its precursor, and that cycloallin itself is one of the precursors in the lachrymatory substance of onions. The characteristic differences between onion, chive and garlic are due principally to the double bond position in the cysteine sulfoxide derivatives. A gas chromatographic method has been developed for detecting benzyl cyanide, -thiocyanate, and -isothiocyanate; it is being used to study three enzyme reactions in crushed land cress seeds.

2. Flavor Components of Hops. The U.S. Brewers Association is financially supporting research conducted to identify the components of hops that affect flavor of beverages, especially beer and ale. The presence in hops of pentadec-6-en-2-one, pentadeca-6,9-dien-2-one and pentadeca-6,9,13-trien-2-one was established. These C₁₅ unsaturated ketones have potent aromas and because they transfer easily into the wort they may be important to the brewing process. Four previously unreported sesquiterpenes of hops were also isolated and identified as ylangene, beta-ylangene, probably beta-copaene, and tentatively a beta-santalene type. A careful and thorough capillary gas chromatographic (GLC) study of the oils from five American hop varieties has been made. This provides a method for identifying varietal origin of unknown samples of hops or hop concentrates.

Humulone isomers (normal, co- and ad-) isolated by countercurrent distribution were well characterized by nuclear magnetic resonance and mass, infrared and ultraviolet spectrometry. These are being used as standards in attempts to develop a rapid GLC method of analysis of the different humulone isomers in unknown mixtures. An entirely glass GLC system was necessary for consistent results. Silyl derivatives of pure humulone gave two peaks on GLC, probably corresponding to the two possible cis:trans forms.

C. Color, Texture, and Other Quality Factors

1. Controlling Consistency of Tomato Products. We have completed a study of the basic mechanisms of fouling during transfer of heat in the evaporation and heating of liquid foods. Quantitative measurements of fouling rates were obtained from a pilot plant in which stainless steel test sections were externally heated by steam while fouling liquids flowed inside. The fouling data collected under this project and its predecessor were deemed too complex in the interrelationships of the many variables to be of immediate and widespread use to the food industry. However, the data were capable of mathematical analysis. Therefore, it was thought that a much more useful product of this research would be a control scheme for

evaporators, encompassing all the collected quantitative data on fouling rates in long tube evaporators. A mathematical statement of our results showed that feed solids variations were such as to suggest a feed-forward control system manipulating feed rate. Extreme variations in feed solids concentration are quite common in commercial practice. The objective of any finish-evaporator is to produce an unvarying product solids concentration. This is most commonly done by manipulating steam temperatures. As our data showed, this procedure is self-defeating, since fouling rates increase with the temperature of the wetted surface of the heat exchanger wall. To achieve a constant product solids output, and also to minimize fouling, a feed-forward-feed-back control scheme was developed. This system would maintain a constant surface temperature despite varying evaporation demand. This control scheme was mathematically simulated on our analog computer and found to be workable. Physical testing of the control scheme was conducted using inline optical refractometers as the continuously monitoring sensing elements to measure feed, and product solids variations. The outputs from these instruments constitute the feed forward and feed back loops around a long tube evaporator, and are mathematically correlated through an analog computer to physically adjust the feed rate to the evaporator. Although this is rather a sophisticated control mechanism for the food industry at the present time, we hope it is a forerunner of things to come. This will result in a piece of automation which could dramatically reduce costs for food processors since it will increase the amount of water evaporated between cleanouts of heat exchangers.

2. Frozen Vegetables of Improved Texture. The pack of frozen vegetables in the U.S. is approximately 2 billion pounds per year with a wholesale value of about 500 million dollars. This volume represents only 2 to 4 percent of vegetables consumed in this country. The growth of the frozen vegetable pack has not measured up to earlier expectations.

We are studying the effects of processing on tissue structure, composition and enzyme activity as they relate to the texture, color and other characteristics of frozen vegetables. In air-blast freezing, -70° C. is the lowest temperature at which microscopically visible tissue damage has been detected in green beans. Appraisal panels distinguished only with difficulty texture differences between green beans frozen in a -70° C. air blast and those frozen in liquid nitrogen (LNF). No difference was detected between LNF green beans stored 1 year at 0° and those stored 1 year at -20° F. A microwave oven was used to blanch corn-on-the-cob. Heating to a center temperature of $200-207^{\circ}$ F. in 4 to 6 minutes resulted in a higher degree of peroxidase inactivation than did a 12-minute blanch in steam or boiling water. The flavor of microwave-heated corn was as good as that of steam-blached corn.

Formation of "delay off-flavor" was studied by holding commercially vined peas at 50, 63, 65 or 80° F. before freezing. Appraisal panels found

highly significant flavor differences between control samples processed with minimum delay and the samples held 2 hours at 80°, 4 hours at 63-65°, or 7-8 hours at 50° F.

Research supported in part by the National Association of Frozen Food Packers showed that green beans and strawberries frozen extremely rapidly by immersion in liquid nitrogen have better texture than those frozen more slowly by conventional methods. This was confirmed by organoleptic evaluation. The explanation appears to lie in the microscopically visible evidence of tissue damage in conventionally frozen green beans which is absent in similar material frozen in liquid nitrogen. Slow freezing causes tangential separation of cells in the outer parts of the tissue, and cell rupture in the radial direction nearer the center. The distribution of the effects appears to be related to tissue structure. If the tissue is composed of thin-walled cells, the cell walls break during freezing. If the walls are sufficiently thick and strong, they remain intact, but cells separate from each other. Of the successive steps, blanching, freezing and cooking, only the freezing actually causes such microscopically visible damage to vegetable tissues. The two forms of damage are found only in slowly frozen products. They are not found in material frozen by immersion in liquid nitrogen or by other rapid freezing techniques. Methods providing intermediate freezing rates cause intermediate amounts of damage.

Sensory appraisal panels are able to recognize the texture changes accompanying cell wall breakage. Quite small differences in amount of damage can be recognized, even though they do not produce appreciable texture differences. The crisp character of fresh vegetables such as green beans is preserved by rapid freezing, as with liquid nitrogen.

Preliminary studies on the rate of release of intact cells from cut surfaces of vegetable pieces by action of pectinase suggested that this might be a useful measure of changes which occur in the intercellular materials during cooking, and during the initial stages of freezing before much of the water has been transformed to the solid state. However, subsequent investigations revealed wide variations in the response of tissues within the maturity ranges commonly used for processing, which severely limited the utility of the method and the study was terminated.

The shear-press has been applied to the measurement of texture differences in samples of green beans which have been exposed to various processing treatments. It was found that within a single lot of material the processing treatments could be compared in terms of maximum force required or work performed to shear the samples. However, sample differences are not sufficiently characterized by the shape of the recorder tracings to describe or permit the qualitative identification of samples. Fresh and frozen beans, after cooking, have similar shear properties. The shear press is therefore not a suitable instrument to measure quantitatively the loss of crispness that is caused by freezing.

D. Microbiology and Toxicology

1. Reducing Heat Requirements to Sterilize Canned Low-Acid Foods. The remarkable heat resistance of bacterial spores is responsible for the severe heat processing required for canned vegetable products and other foods. The severe processing is responsible for serious losses in texture, flavor, and nutritional quality. The basis of heat resistance in bacterial spores remains poorly understood, but basic knowledge of spores and techniques for their investigation are developing rapidly. It is now reasonable to hope that the molecular mechanisms that endow spores with heat resistance will be understood and methods for disrupting these mechanisms may be adaptable to practical preservation problems.

Many different species and strains of spore-forming bacteria require the presence of specific chemical compounds if they are to germinate. A supersaturated solution of calcium dipicolinate was known to act as a general germinant by by-passing such strain-specific germination requirements. 4H-pyran-2,6-dicarboxylate was synthesized and its calcium chelate was found also to act as a general germinant. This heterocyclic compound generally resembles dipicolinate but has an oxygen in the ring instead of a nitrogen. For research purposes it has the advantage of being active in sub-saturated solutions. Dense solutions of chloral hydrate in water or in glycol were also found to stimulate germination of spores.

A strain of B. macerans from spoiled canned corn was found to exhibit an unusual pattern of germination specificity. The common specific germinants are ineffective, but certain plant extracts are effective. The active factors have been isolated, and identified as fructose plus adenine. Adenine has never before been found to initiate germination. These spores with their unique germination requirements may make possible experiments leading to a better understanding of the basic mechanism of spore germination.

Methods of producing good yields of spores of food-spoilage thermophilic anaerobes are being investigated under a grant made to the University of Illinois at Urbana. The ability to produce these spores in quantity would facilitate research on the heat resistance of this class of organisms. Spores of two strains of Clostridium thermosaccharolyticum contained 13.5 and 16.3% lipid that required hydrolysis for extraction. This is far above what has been found in other spores. The fatty acids contained from 14 to 18 carbon atoms; some had one double bond; and one C₁₈ acid had an OH group. The unusually high bound fatty content of Cl. thermosaccharolyticum spores may be related to their unusual dormancy, heat resistance, or "reluctance" to sporulate well.

Detailed investigation of the enzyme activities of cell-free extracts of vegetative cells grown on glucose or on pyruvate indicates substantial differences that appear to result from feedback inhibition of enzyme biosynthesis rather than from a direct repression of enzyme activity by pyruvate.

Sporulation requirements of these strains, cleaning procedures, composition, germination requirements, and heat resistance have been determined. Resistance was increased to $D_{110^\circ \text{C}}$ values of 37 and 46 minutes by "maturation" in water or in pH 5.7 calcium acetate at 58°C .

We are conducting research to determine the mechanisms in bacterial spores that stabilize them against heat and germination, to reduce heat-processing times for low-acid food products. The hypothesis that "physiological germinants" act as allosteric effectors for proteins with functions in dormancy maintenance and release could account for the bewildering variety of highly specific germinants that act on various strains of spores. The adenine-requiring strain of B. macerans and B. megaterium are useful organisms to test this hypothesis. Adenine or 2,6-diaminopurine, with fructose or ribose, induces germination of B. macerans 7X1. Adenosine or inosine are ineffective. Response varies with cation load on spores; calcium spores respond best to adenine. Dipicolinate analogs have stringent shape requirements for Ca·DPA-type germination of B. megaterium. Ca·4H-pyran-2,6-dicarboxylate is effective; Ca·4-methyl-dipicolinate is marginally effective. Ca·Isophthalate, with a low calcium association constant, is ineffective.

The National Institute of Agronomic Research in Paris, France, supported by P.L. 480 funds, is conducting research to isolate and characterize enzymes essential for spore germination. In studies of Bacillus subtilis spores, a relationship was sought between action of amino acids on spore germination and the properties of alanine dehydrogenase and leucine dehydrogenase. A procedure was designed to obtain highly purified enzymes from vegetative cell extracts. Spore germination was observed by electron microscopy. Amino acids that initiate spore germination activate the two enzymes studied. Cytological modifications visible by electron microscopy are dependent upon activity of the enzymes.

2. Controlling Microbial Contaminants in Processed Vegetables. Sources and magnitude of microbial contamination in processing frozen vegetables are being investigated and the influence of new processing methods on microbial contamination is being evaluated. Evidence is growing that use of in-plant chlorine to supplement sound sanitary practices enables freezers to meet the 50,000 count/gram specification required by some industrial customers. Vegetable samples taken from five plants showed marked reduction in total plate count in four plants, no improvement in the other. Coliform content did not parallel total plate counts. The coliform index in samples with counts of more than 250,000/gram was never over 11/gram. Aerobacter spp. were most frequently found; Escherichia coli was found in 3% of the samples. Organisms resembling the slime producer Sphaerotilus natans were recovered from samples from the plant having the highest count. Air conveying of blanched vegetables did not lead to increased counts in three plants where the system was used. In an installation where air conveying replaced a gooseneck elevator and three conveyor belts, a marked reduction in bacterial numbers resulted.

Contract research to reduce microbial contamination that arises in the processing of dehydrated vegetables has been initiated at the University of Illinois at Urbana.

E. Technology--Process and Product Evaluation

1. Dehydrated Vegetables of Improved Stability. The wholesale value of dehydrated vegetable products, exclusive of potatoes, in the United States has been estimated at about \$75-\$80 million annually, representing \$25-\$40 million in fresh vegetables used. Advantages of dehydration over freezing and canning include savings in costs of packaging, storage and transportation through weight and space reduction gained by removal of water from the products.

We are conducting research to develop chemical and technological information to improve the stability and acceptability of dehydrated vegetables. Curled and plain leaf parsleys were analyzed for total beta-carotene, total xanthophyll, all-trans beta-carotene, and the cis-isomers, neo-beta-carotene B, and neo-beta-carotene U before and after blanching, sulfiting, air drying at 66° C. and bin drying at 47° C. Sulfited samples contained approximately 15% more total beta-carotene and xanthophylls than comparable unsulfited samples. Initial blanching or dehydration of unblanched samples gives apparent increases in assay values for total beta-carotene and xanthophylls, indicating instability of the carotenoids in raw parsley held under refrigeration or in the frozen state, or incomplete recovery from the raw product. The percentage of all-trans beta-carotene in the total beta-carotene fractions ranged from 76.1-80.4 in the unblanched, undehydrated samples to 64.6-75.9 in the dehydrated samples.

Contract research concerned with compositional and structural changes relating to the mechanism of water movement and factors influencing recovery of textural qualities has been concluded at the University of California, Davis. As determined by Lee-Kramer shear press tests and taste panel evaluations, differences were found as to the degree of dehydration permissible for carrots, celery, green beans, green bell peppers, onions, and mushrooms, before there was a loss of textural quality, or lack of crispness when the vegetables were reconstituted. Both green beans and celery were found unacceptable after only partial drying to levels of 60-67% moisture. Green bell peppers were judged "acceptable" after reconstitution when dried down to 11.8% moisture. With mushrooms, onions, and carrots, loss of textural quality as judged by taste panels was reflected in lower shear press values. For mushrooms, irreversible loss of normal texture occurred at between 18 and 27% moisture, but mushrooms dehydrated to 6.3% moisture were still judged acceptable after rehydration. Onions and carrots showed loss of normal texture when dried to moisture levels of 38 and 51%, respectively, but did not show decreases in shear press values after reconstitution, until dried to moisture levels of about 22 and 34% respectively.

Several vegetables were studied under various dehydrating conditions such as lyophilization, and high, intermediate, and low temperature drying by conventional procedures. Water vapor sorption properties and cellulosic crystallinity changes were studied. For onions, rehydration was most rapid with lyophilized tissue and this was found to be related to the structural porosity of the tissue which resulted from this form of drying. At 25° and 91° C. rehydration temperature, the original fresh tissue volume was attained in 15 to 30 minutes even though the highest degree of change in cellulosic crystallinity was found in onions dehydrated by lyophilization. Thus, the effect of tissue porosity does overcome the negative effects of increased crystallinity of cellulose with regard to readiness of rehydration. Final rehydration volumes were reached much more slowly with samples subjected to the other methods of drying and were much lower than original, fresh volumes. Cellulosic crystallinity was not significantly affected by drying temperature.

In green bell peppers the greatest increase in cellulosic crystallinity occurred with lyophilization. Some differences were observed between unpeeled and peeled (cuticularized skin removed) peppers, mainly in drying rates and rates of rehydration rather than in cellulosic crystallinity. Rehydration volumes in both cases were slightly greater at 25° C. than at 91° C.

Unlike onions, freeze-drying of green bell peppers did not produce the driest product. Data on cellulosic crystallinity indicate that changes in rates of rehydration and rehydration volume, and consequently in texture, are accompanied by changes in molecular configuration of the cellulose. That crystallinity changes in green bell peppers are not great is reflected in the comparatively small changes in textural qualities.

Onions, celery, and mushrooms were selected to study effects of degree of dehydration upon metabolic activities in relation to texture loss. Although the vegetables showed differences in rates of change in metabolic activity upon dehydration, these were not clearly related to irreversible texture change. In all cases, however, loss of metabolic activity (measured in lieu of measuring death of the tissue by drying) was accompanied by irreversible texture loss. There appeared to be a correlation between decreases in permeability and changes in texture. This occurred at a certain moisture level during drying, rather than at a constant rate.

It had been hoped that results of the study would indicate the feasibility of some means of partial dehydration of certain vegetables without irreversible texture loss upon reconstitution. The results, however, were distinctly negative with respect to this particular objective. Loss of tissue turgor responsible for fresh vegetable crispness has long been known to result when the tissue is killed, as by partial or complete dehydration. The results of the study indicate even further that only slight changes resulting from dehydration preclude the possibility of reconstituting most vegetables to a textural quality even approaching

crispness. However, in some vegetables, as onion and green bell peppers, reconstitution volumes may nearly equal fresh tissue volume. This is particularly the case with their freeze-dried products, in which tissue porosity, and comparatively less shrinkage during freeze-drying, tend to preserve gross-structural conditions despite increased cellulosic crystallinity.

2. Convenience Products from Dry Legumes. Michigan State University at East Lansing is conducting contract research which will lead to the commercial scale-up of rapidly rehydrating precooked powders from dry beans, peas, and other legumes. Cooked whole pea beans, dry peas, and lentils were successfully dried to "instant" powders. With beans, a single drum dryer with applicator rolls had a capacity of 6.64 lb. solids per hour per square foot of drum surface at a sheet moisture content of 5.2%. Capacity with a double drum dryer was about the same. Pureed cooked beans and lentils could be dried only on the single drum dryer; the purees gelatinized in the trough of the double drum dryer. Pureed cooked beans were successfully dried in a horizontal co-current spray dryer. The effects of various operating variables on capacity, product moisture, and mechanical and physical properties were determined. Spray-dried powders reconstituted somewhat more easily than did drum-dried, but a taste panel could not detect any difference after reconstitution.

To improve domestic and export markets for legumes, we are studying the composition and properties of dry beans, peas, and lentils. The aim of this research is the development of products which feature convenience in use and non-flatulent characteristics. In a cooperative study with the Department of Nutritional Sciences at the University of California at Berkeley, flatus and breath gas analyses were made on human subjects.

Immature Ventura variety Lima beans caused much less flatulence in human subjects than did mature (dry) Limas. An equal weight of dry navy beans produces more than twice the flatulence caused by mature Limas. When stachyose and raffinose, found in legume seeds, are fed to human subjects in amounts corresponding to 100 grams of dry beans, breath hydrogen rises markedly but gas passed rectally does not increase. These sugars apparently account for part of the bean-produced gas. Excitement can cause increased levels of both breath hydrogen and rectal flatus. Breath methane appears unrelated to flatulence; about 30% of people have little or no breath methane, in others the level may fluctuate on a 1- to 10-day cycle.

In storage tests of dry beans, cooking time for presoaked dry Lima, Sanilac, or pinto beans at 15.5 to 16.7% moisture increases 2-1/2- to 5-fold during storage for one year at 70° F. No parallel change occurs in rate of rehydration or in three major fractions of the pectic constituents.

Our Pasadena Laboratory is also conducting research to develop improved convenience foods from legumes. A process developed for preparing quick-cooking dry Lima beans consists of intermittent vacuum treatment (Hydravac

process) for 30 to 60 minutes in a solution of inorganic salts, soaking for six hours in the same salt solution, rinsing, and drying. The process has been modified for other legumes. Cooking time for most products is 25-40 minutes. Quick-cooking frozen Lima and other beans can be prepared from dry beans by the same process except that the salt-treated products are frozen instead of dried. Cooking times range from about 10 to 15 minutes depending upon variety and processing conditions. Nutritional value of the protein in processed Lima beans is identical to that of untreated beans.

3. Evaluation of Processing Characteristics of New Pacific Northwest Vegetable Varieties. Twenty varieties of Brussels sprouts grown at the Northwest Washington Research Unit of the State Agricultural Experiment Station were evaluated for processing quality in our continuing cooperative research program. Atlanta and Tribune, the only satisfactory varieties, toughened less as they matured than did Jade Cross, the standard variety for the area, although their oblong shape was less desirable.

Various vegetables were frozen by immersion in liquid Freon 12 at -22° F. Freon freezing (FF) times were: snow peas, 20-25 seconds; green beans, 25-30 seconds; cauliflower (1 to 1.5" curds), 90 seconds; asparagus (3/8 to 5/8" diameter), 30 seconds; (5/8 to 7/8" diameter), 45 seconds; Brussels sprouts (1.5" size), 90 seconds; cob corn, 6 minutes; cut corn, 15 seconds - almost as fast as freezing in liquid nitrogen. Shattering of FF vegetables seldom occurs. Occasional lengthwise splits in asparagus and beans are not evident after the vegetables are cooked. FF vegetables are firmer than conventionally frozen vegetables, possess more snap, and more nearly resemble fresh vegetables in texture. Residual Freon 12 in vegetables ranged from 3 to 28 ppm.

4. Removing Radioactive Fallout from Vegetables During Processing. An investigation of the removal of external and internal radioactive materials from vegetables and fruits during processing is underway by contract with the National Cannery Association in Berkeley, California. Tomatoes grown in soil enriched with strontium had 40 ppm. in the skin and 10 ppm. in the juice. Pears similarly grown accumulated strontium in the peel and core much more than in the flesh. Crops grown in soil enriched with cesium showed the following: sweet corn, somewhat higher concentrations of cesium in the pericarp than in the milk; broccoli, higher in the leaf than in the head; spinach, much higher in the root than in the leaf, vein, or stem; tomato, highest in the seeds, less in the skin, least in the flesh. Growing crops were sprayed with a simulated fallout suspension-solution containing cesium-134. Edible parts were harvested and washed or otherwise treated. With spinach, a water wash removed 80% of radioactivity; a detergent wash was slightly better; water blanching was 6 times as effective as steam blanching. Results with broccoli were similar. With peaches, little cesium was found in the flesh after water rinsing and peeling with lye or by hand. An ion exchange treatment of tomato puree shows promise of reducing cesium-134 contamination to safe levels.

5. Improved Tomato Processing. We have been working cooperatively with an industry committee to develop an analytical method for testing raw tomato material to determine its potential capacity to make products of a desirable consistency. Consistency of tomato products is largely determined by the amount and quality of pectic substances. Enzyme systems exist in tomatoes that very rapidly degrade pectic substances as soon as the tissue is disrupted. Processing methods have been developed to heat tomatoes very rapidly as they are crushed in order to reduce the degrading activity of pectic enzymes. We have discovered that by crushing tomatoes in the presence of acid, the enzymes are inhibited so that we can obtain tomato juice that has not been enzymatically degraded. This observation appears quite useful for obtaining a simple reproducible method for analyzing tomatoes for processing quality. Commercial testing of the analytical procedure has taken place in 1966 and 1967. The method also promises to be useful in selection of improved varieties with regard to consistency potential.

We are also applying this new method to a process for making tomato products of controlled consistency. By adjusting the level of acidity at the time the juice is extracted, we can make a high-consistency juice, a low-consistency juice, firm tomato-juice gels, or products like catsup or sauce with intermediate consistencies. Applications were originally made for two public service patents to cover these processes. More recently three additional applications have been filed on process improvements and on a two-step process. Processors will now be able to choose the procedure best suited to their plants for the production of high consistency products. The industry has shown an extremely active interest in the processing developments. The work has been publicized through presentations at scientific meetings, seminars, publications and press releases. More than fifty companies in the U. S. and abroad have expressed an interest. Several large American processors have investigations of this new process underway in their own research departments.

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POTATO UTILIZATION

Eastern Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, has turned to and is becoming more and more dependent upon the development of new and improved processed products to maintain markets and avoid recurring economic disasters. Crop perishability, fluctuations in supply, and inelasticity of demand, result in wide price swings with even slight surpluses. Depressive lows are moderated by advance contracting by processors prior to harvest in producing areas having a substantial processing industry. However, in many processing areas, processing has not yet been developed and vulnerability still exists and is exaggerated by the growing competition of processed potato and other vegetable food products. If processing is to expand rapidly enough to offset progressive decline in fresh potato consumption, a continuing improvement in currently produced products and development of new products is clearly required.

Lack of adequate knowledge concerning the chemical constituents, physical properties, and enzyme systems in potatoes is limiting development of new and improved products and processing methods. Basic research on composition is needed to provide fundamental information on which an applied research program can be systematically and effectively built. Recently developed techniques make possible the isolation, characterization, and analysis of constituents responsible for flavor, color, odor, and texture of many processed food products which were not available to research in the past. Application of such techniques to potatoes and potato products should make possible the improvement of the quality of present products, both freshly processed and following storage, and provide a basis for technological and engineering studies in new product development.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied chemical and engineering research on studies related to processing. The work of the EURDD, involving the services of chemists, biochemists, food technologists and chemical engineers at Wyndmoor, Pennsylvania, and East Grand Forks, Minnesota, is conducted in cooperation with several Agricultural Experiment Stations which supply potatoes of known cultural history and with the marketing research facilities of the Department. The chemical research program includes: isolation and characterization of the amino acid-sugar intermediate compounds responsible for the browning of chips and French-fried potatoes during processing; studies on lipids, which are believed to play an important role in the storage stability of processed potato products, particularly dehydrated products; isolation and characterization of the proteins, which are important from a nutritional aspect and from their possible involvement in textural and processing characteristics; elucidation of the causes of after-cooking discoloration and isolation and characterization of the pigment formed; methods of predicting textural characteristics of potatoes for French-fried potatoes. The Eastern Division's engineering and development research program seeks to

improve the quality, nutritive value and storage stability of dehydrated potato products and to develop more convenient types of dehydrated products, such as "instantized" pieces that rehydrate and cook quickly. The Red River Potato Processing Laboratory, East Grand Forks, Minnesota, has been established to conduct investigations relating variety and other raw material characteristics to quality of established forms of processed potatoes. This Laboratory is a cooperative undertaking of the Red River Valley Potato Growers Association, University of Minnesota, North Dakota State University, and the Agricultural Research Service.

The Federal scientific effort devoted to this area at Wyndmoor and East Grand Forks, Minnesota, totals 13.0 scientist man-years. Of this number, research on chemical composition and physical properties amounts to 8.2, research on color, texture and other quality factors amounts to 2.4, and research on technology-process and product development comprises 2.4 scientist man-years.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 7.5 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Basic studies on potato lipids. Both the amount of unsaturated fatty acids (linoleic and linolenic) and the ratio of these to total fatty acid content start at a relatively high level during early growth and fall off to a low point near maturity. During storage there is only a slight rise in the percentage of unsaturated acids in potatoes. Processing to flakes and dice results in only slight changes in the fatty acid content and little oxidation of the unsaturated acids. It thus appears that a time close to maturity appears to be best for obtaining tubers of best quality for processing.

2. Potato proteins. Gel electrophoresis has demonstrated the presence of 20 bands in the soluble protein fraction of potatoes. One of these is a yellow band which is not an artifact. Separating the components of the soluble proteins is experimentally difficult. One large band detected by ultraviolet absorption techniques does not appear to be a protein when tested by the standard biuret-type reagent.

3. After-cooking discoloration. It has been verified that large potatoes darken more than smaller potatoes of the same lot. Of potatoes which darken, the stem-end is the location of greatest darkening and relative to the bud-end has the following characteristics: (1) low organic acid content; (2) low potassium content, or more probably, a high potassium to citric acid ratio; (3) high polyphenolic content; (4) high sodium content; and (6) low citric acid polyphenol ratio.

4. Reducing sugars and enzyme activity in stored potatoes. The levels of soluble sugars, invertase and invertase inhibitor in Kennebec potatoes of the 1966 crop were similar in many respects to the 1965 crop. Potatoes stored at 65°F. for three months did not develop enough reducing sugars to affect chipping quality. An excess of inhibitor was always present in these tubers. Tubers placed in storage at 40°F. developed high levels of reducing sugars in three weeks. During reconditioning the reducing sugars decreased to levels lower than those observed for the 1965 crop. The variety, 5899-1 (in North Dakota variety), a better chipper than Kennebec, showed a much higher level of excess inhibitor than Kennebec at harvest time. This variety reconditioned to lower levels of reducing sugar than Kennebec.

The inhibitor naturally present is a protein with a molecular weight of about 17,000 atomic mass units. It inhibits potato tuber invertase most effectively at the pH optimum for the enzyme (pH 4.5). Since both the invertase and the inhibitor are proteins, genetic control of these is a promising area for investigation.

B. Color, Texture and Other Quality Factors

1. Texture of French-fried potatoes. Progress has been made in developing an objective test for the quality of French-fried potatoes at the point of consumption. The use of liquid nitrogen for quick-freezing the pieces after frying and the use of a high-speed recorder which permits magnification of the force peaks has given reproducible results. The improved test measured differences in properties as the result of storage that could not be obtained by the use of a taste panel.

2. Pigments formed in potato chip frying. Use of filter paper "chips" prepared with known sugars and amino acids have permitted investigation of the reaction of these substances under conditions comparable to potato chip preparation. The nitrogen compounds included tyrosine, arginine, phenylalanine, tryptophan, histidine, ammonium sulfate, lysine and γ -aminobutyric acid. The sugars investigated include glucose, fructose and sucrose. Sucrose reacts with lysine at 103°C. much more slowly than with the other amino acids studied. Lysine reacts rapidly with glucose and fructose. The polymerization of the reaction products appears to be the cause of darkening in potato chips as heating continues.

Work on isolating the principal browning precursors is continuing.

C. Technology - Process and Product Development

1. Quick-cooking dehydrated potato products. Optimum conditions have been found for puffing 3/16-inch thick potato slices in the batch gun with superheated steam. The maximum charge size for slices was found to be 15 pounds as against 20 pounds for potato dice. Potato dice from Maine Katahdin potatoes of 18% solids are as good in every respect as those made from Idaho potatoes of 22% solids content. The Maine potatoes had less tendency to slough--a desirable attribute. Experiments in the continuous explosion-

puffing pilot plant showed that potato dice tended to clump. This problem was overcome by coating the partially dried pieces before puffing with powdered sodium silico aluminate (0.75% based on potato solids. This additive is rated GRAS). A feed rate of 675 pounds per hour at 18% moisture content, equivalent to about 590 pounds per hour of product at 6% moisture, has been achieved. However, it has not been yet possible to obtain continuously the high degree of puffing obtained with the batch gun. A problem still to be solved is the development of "off-flavors" in the puffing step. Studies have been begun, cooperatively between the Engineering and Development and Plant Products Laboratories, to identify substances causing these flavors.

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POTATO UTILIZATION

Western Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, is becoming more and more dependent upon the development of new and improved processed products to maintain markets and to avoid recurring economic disasters. Crop perishability, supply fluctuations, and the inelasticity of demand result in wide swings in price with even slight surpluses. In producing areas having a substantial processing industry, growers can moderate depressive lows by contracting with processors prior to harvest. However, in many important potato growing areas where processing has not yet developed, growers are still vulnerable and the situation is exaggerated by the mounting competition from processed potato and other food products. A continuing improvement in processed potato products is clearly required if processing is to expand fast enough to offset the progressive decline in use of fresh potatoes.

To improve the quality of processed potatoes, ways must be found to eliminate the stale, earthy, rancid, green, and warmed-over flavors that are sometimes encountered in potato products, including dehydrated mashed potatoes, dehydrated diced potatoes, frozen french fried, frozen patties, and potato chips, and to retain the desirable natural flavor of freshly cooked potato. Research methods recently developed offer an opportunity to isolate and identify the constituents responsible for the natural flavors and the off-flavors, to develop rapid and sensitive analytical methods for their measurement, and to determine the raw material factors controlling formation of the various desirable and undesirable constituents in the fresh potato.

Further improvement in the texture of potato products is also needed. Fundamental histological and chemical investigations could reveal the causes of differences in the texture of potatoes, as a basis for developing improved processing methods.

Enzymes play a great part in the entire compositional pattern of the potato, not only the constituents responsible for flavor, off-flavor, color, and texture, but also those responsible for disorders such as black spot. Black spot causes severe losses, both to those who market potatoes fresh and to those who process potatoes, because trimming costs are sharply increased and yields reduced. Increased knowledge of enzymes is needed as a basis for solving the black spot and similar problems, for increasing use of potatoes by reducing costs, and for improving quality of both fresh and processed potatoes.

Perhaps the most urgent problem presently facing the potato processing industry is the disposal of plant wastes. Establishment of new strict standards for the discharge of plant effluents into lakes and streams will require research in three areas: the effects of modified plant

operations on the volume and nature of wastes, ways of recovering useful fractions from the wastes, and ways of treating the remaining effluent to lower the BOD (biochemical oxygen demand) to an acceptable level.

USDA AND COOPERATIVE PROGRAMS

In the Western Utilization Research and Development Division, basic and applied research on potato products is conducted at the Division headquarters at Albany, California, and by grant funds in Davis, California and under P.L. 480 in Sweden. The chemistry of potato flavor and the compounds involved in deterioration of potato products are studied to provide a basis for new and improved potato processes and products. Histochemical studies are conducted to elucidate factors involved in the texture of potato products. Basic investigations on the enzyme systems involved in potato product discoloration and the mechanism of rancidity development are in progress.

The Federal program of research in this area totals 5.7 scientist man-years including the equivalent of 0.7 scientist man-years for a research grant. Of this number, 0.7 are assigned to chemical composition and physical properties and 5.0 to technology--process and product development. In addition, the Division sponsors two research grants under P.L. 480.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 7.5 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Enzyme Interactions. The University of Gothenburg in Sweden, supported by P.L. 480 funds, is conducting research to determine how metal ions influence enzyme catalysis, as a means to control stability of vegetable products. The enzyme 3-phosphoglycerate kinase (PGA kinase) catalyzes the transfer of phosphate from adenosine triphosphate (ATP) to 3-phosphoglycerate (PGA). Its activity requires the presence of magnesium ion. It was found that magnesium is first bound to ATP and then this complex becomes attached to the PGA kinase at an active site. The PGA is attached at a different site along the chain-like enzyme molecule. The active site in carbonic anhydrase enzyme involves a histidine residue and the sequence of amino acids at the carboxyl end of the enzyme molecule. The amino acid sequence is different for different forms (isoenzymes) of carbonic anhydrase. An active site on the carbonic anhydrase molecule will bind anions or specific sulfonamide inhibitors. The enzyme phosphatase contains zinc atoms combined at two identical sites. Zinc was found not to be essential for binding, but it does influence the binding process. The active site on the molecule of laccase contains two copper atoms bound to nitrogen atoms in the molecular chain,

The mechanism of lipid formation is being investigated under a grant made to the University of California at Davis. Information obtained under this study would be used to find ways to alter the ratio of saturated and unsaturated fatty acids in foods, select vegetables for processing, control oxidation during and after processing, and measure adequacy of blanching. In addition to potatoes, other vegetables are studied under this grant. Spinach chloroplasts contain an inhibitor of acetyl CoA carboxylase, a key enzyme of fatty acid synthesis. It combines with the enzyme and not the substrate, is heat stable, and consists of at least two molecular species. This inhibitor with its thermal stability may be of practical use as an index protein for assessing adequacy of blanching of processed vegetables.

Enhancement of fatty acid synthesis in potato discs occurs at a very early phase of "aging" and to a more pronounced extent than other changes, such as enhanced protein synthesis and respiration. Experiments with antibiotics as probes suggest that the major cause of this enhancement is the increased synthesis of the proteins (enzymes) constituting the fatty acid synthesizing enzyme system. The increased protein synthesis seems to imply the operation of a system for derepression of the operon (complex of genes) coding for these enzymes. This work may eventually yield a clue to means to manipulate the enzymes of a given vegetable so as to enhance desirable and suppress undesirable reactions.

2. Fat autoxidation. The Swedish Institute for Food Preservation Research at Gothenburg, Sweden, is using P.L. 480 funds to study the factors affecting the rate of autoxidation of fat as a basis for the development of improved processing methods for dehydrated potatoes and other vegetables to decrease their tendency to turn rancid. In general, decreasing the concentration of oxygen in the atmosphere did not dramatically lower the rate of fat oxidation. In 1% oxygen the rate was half that in air (20% oxygen). Factors which increase the absolute rate of oxidation, such as higher temperature, stronger illumination, or higher concentration, decreased the rate of oxidation at low oxygen pressure relative to that in air. The effect of added antioxidants was found to be somewhat reinforced at low oxygen pressure due to an extension of the "induction period". Antioxidants prolong the induction period but do not decrease the post-induction rate of oxidation. However combined addition of antioxidants and certain amino acids causes both a prolongation of the induction period and about a 50% decrease in the post-induction rate of oxidation. In the presence of certain added metal ions which generally act as pro-oxidants low oxygen pressure strikingly decreased the relative rate of oxidation.

B. Technology -- Process and Product Development

1. Factors Affecting Color and Flavor Stability of Processed Potatoes. To improve the color, flavor, texture, and stability of frozen and dehydrated potatoes, we are conducting a study of raw material and processing variables. Water-holding capacity of gelled starch was reduced when frozen par-fries

were thawed and held at 45-55° F. for one to several days before finish-frying. Thawed and held fries had a drier texture and two to three times more absorbed fat than those fried immediately after thawing.

Phenoloxidase, peroxidase, and catalase activities were completely retained in freeze-dried potato tissue and in an acetone extract. Phenoloxidase and peroxidase showed no loss of activity in six months; catalase activity decreased after three months. Phenoloxidase activity in extracts from black spot-susceptible and black spot-resistant potato tissues showed no relationship to tissue discoloration when catechol, cresol, tyrosine, chlorogenic acid, and caffeic acid were used as substrates.

Gas chromatography of amino acids and organic acids in potatoes, using several volatile derivatives (silyl-proton exchange, boron trifluoride and N-methyl trifluoroacetyl esterification), is being used with ion-exchange chromatography to determine possible qualitative and quantitative associations with both enzymic and non-enzymic discoloration.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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III. MARKETING AND ECONOMIC RESEARCH

CITRUS AND SUBTROPICAL FRUIT

Market Quality Research Division, ARS

Problem. Research is needed to develop better objective indices for measurement of quality of citrus and other subtropical fruits. This would result in more meaningful grades and standards which could be better enforced. Instrumentation and automatic devices for quality sorting on a commercial basis might be possible. Decays and fruit soilage present serious problems in both domestic and export markets. Much research is needed to relate mechanical harvesting, handling practices, packaging, precooling and transit refrigeration to wastage, and to develop effective treatments for decay reduction. There is need for further research on controlled atmosphere storage for citrus and other subtropical fruits. Problems which are sometimes distinct and sometimes interrelated exist in each of the geographical areas. These often require biological research in the separate production areas for solution.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. Research is conducted in the producing areas of California, Florida and Texas. Market studies are made in Belle Mead, New Jersey and Chicago. P. L. 480 grants are operative for studies in India on identification and mode of infection of fungi causing postharvest rots of tropical fruits; in Spain on detection of additives in citrus juices; in Germany on the antimicrobial action of biphenyl; in Israel on maturation and ripening of avocados; and in India on metabolic changes during ripening of mangos. A contract study on citrus fruit quality as related to mechanical harvesting will be completed in November 1967 at the Citrus Experiment Station, Lake Alfred, Florida.

Total federal scientist man-years devoted to this area is 11.0. Of this 1.5 is devoted to objective measurement of quality; 1.2 to quality maintenance during handling; 3.4 to quality maintenance during storage; 1.0 to quality maintenance during transportation (with emphasis on export); 1.0 to post-harvest physiology; and 2.9 to postharvest disease control. P. L. 480 projects in this area involve \$29,732 equivalent over a 5-year period in India; \$56,163 equivalent over a 4-year period in Spain; \$77,138 equivalent over a 5-year period in West Germany; \$83,620 equivalent over a 5-year period in Israel; and \$45,344 equivalent for a second 5-year project in India.

Projects terminated during this period included: methods to improve quality of grapefruit on European markets (MQ 2-74); and aromatic polynuclear hydrocarbons on citrus fruits (MQ 3-46).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 10.0 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Non-Destructive Sorting of Citrus Fruits for Quality. Hamlin and Valencia oranges from the Orlando laboratory were evaluated at Beltsville on the basis of percent soluble solids, titratable acidity, and Brix acid ratio. Before shipment both varieties had been sorted by eye into 3 groups, according to orange color. Variation of individual oranges within color groups was too great for significant quality differences between groups. Brix-acid ratios for Hamlin averaged 11.6 to 13.4, while Valencia averaged 10.6 to 10.9.

Tests at Orlando on the commercial light reflectance sorter were completed. All tests were made on washed fruit. Sorting for degreening requirement in Hamlin oranges, uniformity of color in Hamlin and Temple oranges and limes and defects of oranges was successful. Decay was significantly higher with advanced maturity, more hours of degreening and weeks of storage. However, initial fruit color had no effect on decay. The biweekly maturity tests on Hamlin and Valencia oranges and Marsh grapefruit show that of 24 measurements in each of 3 seasons, 17 to 19 indicated maturity changes. (MQ 3-77)

2. Seasonal Changes in Florida Persian Limes. Limes from 3 different groves were analyzed for ascorbic acid for 5 consecutive months. Small limes contained more ascorbic acid than large limes. Limes 1-7/8", 2-1/8", and 2-3/8" in diameter averaged 30, 27, and 23 mg. of ascorbic acid per 100 ml. of juice, respectively. Ascorbic acid content also varied between groves. The average ascorbic acid content of limes of all sizes from 3 groves was 31, 26, and 23 mg. per 100 ml. of juice. (MQ 3-53)

3. The Detection of Additives in Citrus Juices. Continuation of this P. L. 480 project in Spain has developed useful clues to adulterants in citrus juices. Data on proportions of mineral constituents, amino acids and flavonoids in pure juices have been obtained. The relation of acidity to quality and purity has been clarified. The development and adoption of simplified, accurate methods of analysis for major and minor components of juice would be of great benefit in commercial detection of adulterants. (E25-AMS-6)

B. Quality maintenance in handling and packaging

1. Citrus Fruit Quality as Related to Mechanical Harvesting. This contract research with the Florida Experiment Station was completed during

the 1966-67 season. Hand harvesting consistently caused less immediate damage and decay during holding than mechanical tree or limb shaking. Of the orange varieties tested, Hamlins showed the least damage and Pineapples the most from mechanical harvesting. Marsh grapefruit generally showed less damage than oranges. Fruit splitting and puncturing are the principal types of damage. Plugged fruit (rind torn at stem end) has generally been less of a problem with mechanically harvested than with hand harvested oranges. (MQ 2-65)

C. Quality maintenance in storage

1. Controlled Atmosphere Storage of Florida Citrus Fruits. Of the various atmospheres tried, 15% O₂-0% CO₂ resulted in the best flavor retention of Valencia and Temple oranges and Orlando tangelos. Unwaxed Valencias stored in 15% O₂ with 0, 2.5, or 5% CO₂ for 12 weeks at 34° F. had higher flavor ratings than comparable fruit stored in other atmospheres or in air. Waxed fruit stored in CA were lower in flavor and had more decay than unwaxed fruit. Less decay developed in fruit held in CA than in air storage. Off-flavors developed in fruit held in 5% O₂ with 0, 2.5, or 5% CO₂. Excessive decay followed 20-week CA and air storage. Air storage at 35° F. was most effective for Orlando tangelos up to 6 weeks. Results at 40° were similar in air and 15% O₂ with 0, 1, or 2.5% CO₂. Stem-end decay increased as O₂ concentration decreased and as CO₂ increased. Temple oranges stored 5 weeks in 15% O₂-0% CO₂ at 35° F. developed no decay and less than 2% chilling injury. More chilling injury occurred in air at 35°.

Acetaldehyde, ethyl alcohol, pinene, sabinene, myrcene, limonene, and octanol were the predominant volatile components present in the citrus fruits tested. Ethyl alcohol, which increased with reduced oxygen and with waxing, showed more variation during storage than other components. Ethylene-treated fruit contained an unidentified volatile component that was not present in non-ethylened fruit. (MQ 2-110)

2. Controlled Atmosphere Storage of California Oranges. Valencia oranges stored at 42° F. with carbon dioxide concentrations of 10% and 20% were off-flavor after 1 month of storage and showed rind injury after 2 months. After 3 months of storage, the control fruit in air was rated best in flavor, with the treated fruit from 21% oxygen and zero CO₂ next. Oranges held in 5% oxygen without CO₂ for 3 months were off-flavor. (MQ 2-98)

3. Controlled Atmosphere Storage of Texas Grapefruit. Grapefruit harvested in late-December showed the least decay when stored in carbon dioxide-free atmospheres. Decay was almost 12 times greater in fruit held in 5% CO₂ after 18 weeks. Oxygen levels from 1.5% to 10% did not affect decay development. Penicillium green mold was responsible for nearly all decay. One lot of grapefruit from the upper Valley which was stored at 45° F. in 10% oxygen and zero carbon dioxide, showed less than 6% decay after 18 weeks in CA plus 1 week in air and an additional 1 week at 70°.

Peel color was retained best in fruit held in atmospheres containing 1.5% oxygen. It was nearly as good in fruit stored in 5% oxygen. Fruit held in 10% oxygen acquired an orange peel color with the blush faded and was similar in appearance to fruit stored in air. Peel color was not affected by the levels of carbon dioxide maintained in the different atmospheres. Rind pitting was least at the higher CO₂ levels. (MQ 2-98)

4. Controlled Atmosphere Storage of Florida Avocados and Limes. Lula avocados retained higher quality after 30, 45, and 60 days in CA storage at 50° F. than comparable fruit stored in air. After 60 days' storage, all avocados stored in 1% O₂-9% CO₂ were marketable, making this the most satisfactory atmosphere tested. Only unwaxed limes subjected to a minimum of handling were satisfactory for CA storage tests. Waxed fruit had too much decay and rind injury. Limes stored in 10% O₂-7% CO₂ at 50° F. retained green rind color for 60 days, but limes in air were too yellow after 30 days. Fruit from atmospheres containing 15% CO₂ developed a severe discoloration of the rind. Juice content of limes usually decreased in CA and increased in air. (MQ 2-110)

D. Quality maintenance during transportation

1. Export Shipment of Texas Grapefruit. A refrigerated van test shipment of red grapefruit was made to West Germany in January 1967. Transit temperature in the van was not optimum. Slow cooling of the grapefruit indicated a short-circuiting in the air flow. A modification in the loading pattern to include a solid, top layer of containers would have been beneficial. (MQ 2-139)

2. Export Shipments of California Citrus Fruit. Average transit temperatures of 13 test shipments of citrus from California to Rotterdam were 46° to 53° F. All the biphenyl residues of the 4 orange and 4 lemon shipments analyzed to date were below the legal tolerance of 70 parts per million on arrival, but some oranges exceeded the tolerance after holding 1 week in the shipping container without refrigeration to simulate wholesale distribution. (MQ 2-139)

E. Postharvest physiology

1. Maturation and Ripening of Avocados. The annual report on this P. L. 480 project in Israel has not been received. A progress report through October of 1966 indicated substantial progress in development of methods for determination of auxins and inhibitors. Avocado tissue cultures have been prepared on artificial media for studies on response to natural and synthetic growth substances. (A10-MQ-2)

2. Metabolic Changes in Mangos During Ripening and Storage. This P. L. 480 project, initiated in India in 1966, has not progressed to positive findings. Several Indian varieties of mangos were used in storage tests and for compositional studies. Chilling injury to the fruit occurred at

holding temperatures below 41° F. Total protein content did not change during postharvest ripening but the proportion of several amino acids changed significantly. Ascorbic acid content decreased during ripening. Indirect evidence indicated that methionine is a precursor for ethylene. The activity of catalase and peroxidase associated with oxidation increased during ripening. (A7-MQ-6)

3. Stylar-End Breakdown of Limes. When stylar-end breakdown was not prevalent in limes from groves and packing houses of the area, handling had little or no effect on the incidence of the disorder. Conversely, when the disorder was prevalent, bruising increased it. Bruising does not cause stylar-end breakdown, but increases the disorder in susceptible fruit. The disorder varied widely in limes from different groves and developed most rapidly during the initial 7 days in storage at 50° F. (MQ 2-64)

4. Factors Affecting Volatile Production by Oranges. The effects of temperature and injury on volatiles emanating from whole Valencia oranges were studied. Volatiles emanating from injured and uninjured Valencias increase with increasing temperature. Volatiles emanating from injured oranges were nearly 75 times as great as those from uninjured fruit. Ethylene treatment increased the production of volatiles by lemons. (MQ 3-89)

F. Postharvest disease control

1. Control of Decay of Florida Citrus Fruit. Five new fungicides were evaluated for control of citrus decay. Four were ineffective. Two-amino-butane (2-AB) base, when used as a fumigant at 12 mg./l. (70°-90° F.), was superior to standard treatments. When applied as a 1% dip or spray treatment, 2-AB phosphate was consistently more effective than the standard 2-AB carbonate. Thiabendazole or hot water + 2-AB carbonate + 2-4,D were more effective during storage than 8 other prestorage treatments for tangelos and Temple oranges.

Decay of specialty citrus hybrids (Lee, Nova, and Page) was directly related to degreening time. Excessive stem-end rot and anthracnose decay developed in fruit degreened for 45 hours or more. A biphenyl-resistant strain of Penicillium digitatum was isolated for the first time in Florida from natural sources. (MQ 2-65)

2. Materials Affecting Spore Germination and Growth of Decay Organisms. Octanal inhibited germination of spores of Penicillium digitatum, Phomopsis citri, and Diplodia natalensis at a concentration of .04 mg/l. Other aldehydes were less effective, and corresponding alcohols were not inhibitory. Terpenes and esters were not inhibitory. Twenty-five volatile components of citrus fruits were tested. Butanal was more effective than any other aldehyde tested in fumigation tests with inoculated oranges. (MQ 2-100)

3. Effects of Controlled Atmospheres on Growth of Citrus Decay Organisms. Reducing the concentration of oxygen in static or flowing atmospheres severely influenced growth rates of Penicillium digitatum in artificial media, and decay rates of inoculated lemons and Valencia oranges. As oxygen was reduced to 2% growth rates and decay rates were reduced slightly, but between 1% and 0% oxygen was very limiting. At 1% oxygen, fungus growth and fruit decay were reduced considerably. At 0% oxygen, there was little or no fungus growth or fruit decay apparent. At the 1% and 0% oxygen levels, fungus sporulation was severely restricted. Non-inoculated oranges and lemons developed off-flavors at 1% or lower concentration of oxygen, and these injured fruits were susceptible to secondary decay on later storage in air. (MQ 2-126)
4. New Market Diseases of Navel Orange. A blemish on Navel oranges from California has been observed during the past season which is new to the Chicago laboratory. It is characterized by the protuberance of one or more of the navel convolutions, which are light to dark grayish-brown, hard, dry and rough, and vary from a few millimeters to two centimeters in size. Fifty-two organisms have been isolated from these protuberances. Reinoculation studies with oranges show that 37 out of 47 different isolates can cause decay. None of the 47 organisms caused a protuberance of the navel convolutions when inoculated back into mature oranges. (MQ 2-64)
5. Market Losses in Oranges During Marketing. Average losses over a 5-month period for California Navel oranges in Chicago market were slightly over 2% at each of 3 market stages, wholesale, retail, and consumer. Florida Valencia oranges during a 3-month period showed higher losses at the retail and consumer level but lower losses at wholesale. In the New York City market area average losses of California Navel oranges at wholesale, retail and consumer level were identical to those reported for Chicago. Losses were caused mainly by blue and green molds. (MQ 2-132)
6. Postharvest Diseases of Tropical Fruits. Continuation of this P. L. 480 research in India has resulted in identification and description of numerous diseases which cause market losses in tropical fruits. Additionally 14 fungicides were tested for postharvest application and heat treatments were evaluated for decay control in mangos. Hot water treatments were not successful for bananas because of fruit injury. Determination of optimum amino acid composition of culture media has developed useful information for in-vitro studies of many of the decay organisms. (A7-AMS-6)
7. Antimicrobial Action of Biphenyl. This research, which is done under a P. L. 480 project in Germany, is developing potentially useful information on the mechanisms of the inhibiting action of biphenyl on growth of decay producing organisms. Studies have shown an inhibiting action on respiration and carbohydrate metabolism. Studies with pure enzymes have shown that lactic acid dehydrogenase is inhibited by .07% sodium orthophenylphenate. Biphenyl inhibits the same enzyme in concentrations of 0.5% and higher. (E10-AMS-3)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Quality Maintenance During Storage

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- T. T. Hatton, Jr., and W. F. Reeder. 1967. Controlled atmosphere storage of Keitt mangos--1965. Proc. Tropical Region, Amer. Soc. Hort. Sci. 10:114-119. (MQ 2-110)

Quality Maintenance During Transportation

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Postharvest Disease Control

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DECIDUOUS FRUIT AND TREE NUTS

Market Quality Research Division, ARS

Problem. Deciduous fruits and tree nuts are subject to deterioration after harvest through normal metabolic processes and from decay organisms. In addition, these products vary widely at harvest in the characters that determine market acceptance. Practical objective measurements of quality would greatly assist in standardization and grading procedures, and the development of instrumentation for this purpose increases the chance for automatic quality sorting on a commercial basis. Additional information on physical and chemical methods for decay reduction and on product quality as related to mechanical harvesting would be useful. Research is needed on storage environment as related to temperature, air movement, humidity, atmosphere modifications and fumigants. Research must be continued with transportation equipment and services as affecting ultimate quality of the product in the market. Dried fruits and tree nuts are subject to insect infestation while drying in the field, during storage while they await processing, in the processing plant and in marketing channels until they reach the final consumer. Research is necessary to develop more effective measures for preventing insect infestation all along this line. Emphasis must be given to finding methods that will avoid both insect contamination and pesticide residues.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of basic and applied research involving horticulturists, plant physiologists, plant pathologists, entomologists and food technologists. The research includes definition, measurement, and maintenance of quality during the period between harvest and consumption. Locations include Beltsville, Md.; Wenatchee, Wash.; Fresno, Calif.; Raleigh, N. C.; Chicago, Ill.; and Belle Mead, N. J. Cooperative agreements and limited contributed funds are in effect with the California Strawberry Advisory Board. P. L. 480 supported research is underway in Finland on the effects of pesticide sprays on the storage life of certain fruits. Limited support under cooperative agreement is provided for pear studies at Oregon State University and the University of Maryland.

There is also a continuing program headquartered at Fresno, California, where entomologists are engaged in basic and applied research directed toward the prevention and control of insect infestations in dried fruits and in tree nuts after harvest. The work is conducted in cooperation with California State and County agencies and several industry groups. Much of the cross-commodity research at Savannah, Ga., reported in Area 13, "Insect Control in Marketing Channels," is also applicable to the problems in dried fruits and tree nuts.

Federal effort in this program totals 20.7 scientist man-years divided as follows: Objective measurement of quality 3.0; quality maintenance in handling and packaging 1.5; quality maintenance in storage 3.0; quality maintenance during transportation 2.0; postharvest physiology 1.0; postharvest disease control 4.2; and prevention of insect infestation 6.0.

Research under P.L. 480 includes a 5-year project in Finland for \$96,441 equivalent, involving the effects of pesticides on storage life and composition of fruits; and a 5-year study in Poland for \$34,967 equivalent, on the ecology of mites attacking dried fruits and herbs.

A 3-year cooperative agreement with the California Department of Agriculture for research to determine the morphological and taxonomic characters of immature stages of Carpophilus continues through June 1970.

Projects terminated during this period included: Film liners for fruit (MQ 2-63), Effects of high nitrogen during simulated transit on fruits, (MQ 2-71), Ozone on fruits (MQ 2-102), and Anthocyanins in cherries (MQ 3-100).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 19.9 scientist man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Eastern Apples. At harvest, two different light transmittance signals separated Red Delicious apples into four or five significantly different categories, but only two or three significantly different groups could be detected by the taste panel and objective tests. Preliminary data indicates that the light transmittance signal Δ O.D. 580-640 nm is at least equal to the previously used Δ O.D. 700-740 nm, which is specific for chlorophyll in evaluating quality. (MQ 3-95)

2. Western Apples. Starking Delicious apples sprayed with "Alar" during growth were slightly more acid than check fruit at harvest and after 8 months in storage. Treated fruit averaged about 1 pound firmer at the end of 7 months' storage than the controls, and did not have a typical flavor. There were no consistent differences between Alar-treated and non-treated Golden Delicious apples.

Starking Delicious from an orchard with the lowest foliar nitrogen had the least chlorophyll, highest acidity, and were firmer after storage for 9 months than fruit from 2 other orchards with higher foliar nitrogen. Golden Delicious apples softened most during the first 1 to 2 months in storage. Firmness was inversely related to fruit size at harvest and the differences were

greater with delayed harvest. During storage, firmness declined more rapidly in the small than in the large fruit. Soluble solids were consistently higher in yellow than in green fruit and reached a maximum in the fruit harvested 145 days from bloom. Total acidity decreased 20% between the 145 and 155-day harvests. (MQ 3-95)

3. Fruit measurements using electrical properties. Techniques for evaluating the electrical properties of fruits and vegetables over a wide frequency range are being developed. Initial tests with flesh from apple shows a progressive decline in resistivity as the frequency increases from 10 to 100,000 Hz (6500 ohm-cm at 10 Hz to 900 ohm-cm at 100,000 Hz). By keeping the potential across the tissue low (4.0 volts/cm), stable readings are obtained over several minutes. Measurements of electrical properties are now being made on fruit of varying quality to determine the degree of correlation between electrical properties and selected quality factors. (MQ 3-90(GR))

4. Physical properties of pome fruits that affect equilibrium position. The physical properties of size, shape, weight, density, etc., of pome fruits are being cataloged to provide information needed in the design of automatic machines for handling and sorting of the fruit. Physical properties which have been cataloged include: specific gravity, coefficient of friction on different surfaces, orientation in water, position of center of gravity, volume, surface area, mean radius, surface roughness, and size and shape of stem and calyx indentations. The properties have been measured on McIntosh apples from New York and Michigan, Red Delicious apples from Washington and Michigan, Rome apples from Washington, and Jonathan apples from Michigan. The variability within varieties, between varieties, between varieties, and between producing areas have been determined. Additional physical properties are being evaluated in the same way. (MQ 3-87 (C))

5. Sonic Resonance Techniques. The mechanical properties of the flesh of fruits and vegetables are often the chief determinant of fruit texture. The elastic characteristics (modulus of elasticity) and the inelastic properties (internal friction) of some fruits and vegetables were measured during various stages of development. Modulus of elasticity has been reported to be linearly related to the turgor pressure within plant cells. In terms of the textural attributes of whole fruits and vegetables, we have argued that it should be most closely correlated with "firmness" even though some relationship to "crispness" may also exist. Because of the lack of objective definitions for these words, they are not as accurate or useful as one might desire for reporting research results.

Softening of bananas during ripening was associated with a decrease in Young's modulus of elasticity from 272×10^5 to 85×10^5 dynes/cm² as the peel color changed from light green to yellow. Modulus of elasticity was significantly and directly correlated with percent starch content. During ripening, internal friction increased from 0.073 to 0.165, being inversely correlated with the elastic modulus ($r = -0.88$, $df = 58$).

For late Elberta peaches, the modulus of elasticity decreased rapidly from 1925×10^5 dynes/cm² 3 weeks prior to the estimated date of maturity to 195×10^5 dynes/cm² 2 weeks after estimated maturity. Kieffer pears exhibited a more gradual decline from 2884×10^5 to 1151×10^5 dynes/cm² over a 3-month period of development and maturation. For apples, Young's modulus of elasticity generally declined during the early period (90 to 115 days after full bloom), then remained relatively unaffected as the fruit approached maturity, and finally, declined as the fruit ripened on the tree.

With the exception of apples, therefore, the fruits studied exhibited a decreasing modulus of elasticity with advancing stages of development, maturation, or ripening. This mechanical parameter, therefore, may be useful in the future as a more objective and better defined index of firmness, or possibly for estimating stage of maturation or ripeness of fruits.

Recent efforts have been devoted to techniques for measuring sonic resonance within whole intact commodities. An exploratory taste panel's evaluations of ten apples from 2 different storage conditions indicated the frequency of resonance was more highly correlated with texture ($r = 0.86$) than with juiciness ($r = 0.79$). Of a variety of objective measurements which were compared with the sonic resonant frequency technique, the "mechanical thumb" force was best correlated ($r = 0.79$).

Under a research contract, the proposed "acoustic maturity constant" was evaluated for three varieties of apples. This constant, f^2m , combines the square of the resonant frequency and the mass of the apple. Apples harvested over a 7-week period gave a correlation coefficient of 0.84 between f^2m and Magness-Taylor pressure value, but only 0.12 between f^2m and soluble solids. Thus it appears the f^2m value may provide a good indication of apple firmness, but not of maturity. Previous tests had also shown the f^2m value to correlate with firmness. (MQ 3-72 (C))

B. Quality maintenance in storage

1. CA Storage of Eastern Peaches and Nectarines. Peaches: Storage of firm ripe Loring and Redhaven peaches for 6 or 9 weeks in air at 32° F. was not satisfactory. The fruit developed internal browning and failed to attain acceptable quality when transferred to 65°. Peaches stored in 1% O₂ and 5% CO₂ at 32° for 9 weeks and ripened in air at 65° were of better quality according to taste panelists, than fruit from any other atmosphere and were free of internal browning.

Nectarines: Late Le Grand nectarines responded somewhat the same as the peaches. However, a 21% O₂ - 5% CO₂ atmosphere was about as good a storage atmosphere as the 1% O₂ - 5% CO₂ atmosphere. Lowered O₂ and increased CO₂ concentrations independently reduced development of decay during storage and ripening, but did not control it effectively. Nectarines developed less decay than peaches. (MQ 2-99)

2. CA Storage of Western Nectarines. In tests at Wenatchee, Washington, atmospheres containing 5% CO₂ were the most favorable of 10 different atmospheres tested for holding nectarines at 31° F. The O₂ level within the limits of 1 to 21 percent did not appear to be a critical factor. The dessert quality of the fruit in 5% CO₂ in air or in an atmosphere with low levels of O₂ was good after 8 weeks of storage. (MQ 2-99)

3. Storage Life of Apples as Related to Rate of Cooling. Hydrocooling Starking and Golden Delicious apples soon after harvest was not significantly better for prolonging storage life than air-cooling in cold storage rooms in which the fruit was cooled to 32° F. in 3 days or 7 days. At 3 examination periods during up to 8 months' storage at 31°, no consistent differences in flesh firmness, soluble solids, total acid or taste panel evaluations were found between hydrocooled apples and those air-cooled in 3 and 7 days. However, the quality of fruit that required 14 days to cool was lower after each storage period. (MQ 2-127)

4. Season Temperatures as Related to Storage Quality of Pears. Preliminary results of research at Hood River, Oregon, confirm the generally held opinion that Bartlett pears have poorer storage quality when harvested after a cool season (as determined by either minimum or maximum temperatures or by heat units during the 9-week period following full bloom) than when harvested after a warm season. Quality of Bartlett pears harvested at different maturities in 1965 (a warm season) ranged from about 9.5 to 11.5 (on a scale in which 12 represented highest quality). In 1964 and 1966 (cool seasons) quality ranged from about 7.5 to 9.5. Similar differences between seasons was not evident in Anjou pears. (Cooperative Agreement, Oregon State University)

C. Quality maintenance during transportation

1. Domestic Air Shipment of California Strawberries. Strawberries shipped via jet cargo planes from California to eastern markets in the fall of 1966 averaged $16\frac{1}{2}$ hours in transit. Average ambient temperatures ranged from 58° to 68° F., being in the low sixties most of the time. Strawberry temperatures averaged between 41° and 53° F. and gradually rose from shipping point to delivery at the wholesalers. Top layer temperatures averaged about 8° warmer than middle layer temperatures. Sealed, coated pallet covers with dry ice enclosed, produced atmospheres that averaged about 16% CO_2 and 15% O_2 . Berry decay was slightly less in the sealed covers than in the regular or partial covers but the differences were not significant. (MQ 2-83)
2. Export Air Shipment of California Strawberries. Strawberries shipped by air from California to European markets averaged 28.5 hours in transit. About one-half of this time was spent in flight, 42% in airports, and 9% in transit to the airport. Average temperatures of precooled strawberries shipped in fiberboard pallet covers were about 38° F. at origin and ranged from 44° in the middle layer to 57° in the top layer at destination. Sealed polyethylene coated pallet covers with dry ice enclosed averaged about 16% CO_2 and 14% O_2 in transit. Nitrogen-refrigerated airline containers helped maintain initial berry temperatures, but did not reduce the temperatures significantly if the berries were not cool when placed in the container. Atmospheres in the containers ranged from 0.5% O_2 to 12% O_2 ; CO_2 did not accumulate significantly. Decay averaged about 3.0% one day after arrival at European airports, when the berries were shipped in regular fiberboard pallet covers. It was about one-half as much when coated covers were used to produce high CO_2 atmospheres. Fewer soft berries developed in the coated covers than in the regular covers or the nitrogen-refrigerated containers. (MQ 2-83)
3. Rail Shipments of California Strawberries. Palletized strawberries in mixed loads with lettuce were shipped in mechanically refrigerated cars via freight service from California to New York. Temperatures in the centers of pallets averaged about 7° F. above the thermostat settings (34° or 36°). Heavy polyethylene covers over the pallets did not affect transit temperatures but caused injurious atmosphere modification when used in combination with dry ice or "Tectrol" atmospheres (10% CO_2 - 5% O_2 initially). Heat-pasteurized berries shipped in a modified atmosphere had no decay on arrival, and substantially less decay than the untreated berries after 1 and 2 days at 60° F. (MQ 2-83)

D. Postharvest physiology

1. Scald Control for Eastern Apples. New commercially available diphenylamine liquid concentrates were as effective in controlling scald on Stayman, Red Delicious, and Rome Beauty apples during 6 months' storage at 32° F. as the standard 83% wettable powder formulation. Ethoxyquin was as good as diphenylamine for scald control on these varieties but caused some slight calyx burning on Rome. A 30-second dip in 130° water continued to give good

scald protection on Stayman but for Delicious 5 minutes in 120° water gave better scald control and was safer than the shorter dip. Hot-water treatments markedly reduced scald on Rome apples but some fruit usually was injured. Treating apples in a microwave oven for 10-30 seconds gave little scald control and caused some core area desiccation. (MQ 2-91)

2. Scald Control for Western Apples and Pears. Green and yellow Golden Delicious, Red Delicious and Winesap apples were packed with wraps with and without chemical scald inhibitors. The best scald control and least injury on Golden Delicious was obtained with ethoxyquin treated wraps. Red Delicious and Winesap apples responded best to a DPA wrap. Red Delicious apples harvested early developed more than 25% scald regardless of treatment, but early- and late-harvested Golden Delicious both responded well to the ethoxyquin wrap. Anjou pear scald was controlled best with a dip of ethoxyquin plus tutane. Wraps without incorporated ethoxyquin were ineffective.

Red Delicious apples from an early harvest, waxed shortly after picking, developed severe scald during storage. Inclusion of diphenylamine (DPA) in the wax did not reduce scald. Waxing Golden Delicious apples reduced scald development approximately the same amount oil wraps did, but not enough for commercial control. The inclusion of scald inhibitors, DPA, and ethoxyquin in the wax did not improve scald control. DPA caused a surface discoloration which was similar, but not identical to typical scald. Wax applied 4 days after Anjou pears were harvested, increased scald on fruit stored for 6 months. Inclusion of Stop Scald (ethoxyquin) in the wax reduced scald development only slightly. (MQ 2-91)

3. Effects of Pesticides on Composition of Fruits. The postharvest application of CIPC did not have any measurable effect upon the concentration of ascorbic acid, organic acids, amino acids or pectic substances of apples and strawberries while stored at 5° or 10° C. Respiratory activity of the fruit was also not different from untreated fruit. (E8-AMS-6)

4. Vitamin E content of apples. Vitamin E content increased during development of the fruit on the tree but declined after 4 months in storage. Although vitamin E could serve as an antioxidant for the peroxidation of linolenate no direct correlation between ethylene production and vitamin E content was found. Preliminary results with ethylene and some growth substances indicate that ethylene can halt the action of gibberellin on tissue elongation.

E. Postharvest disease control

1. Stem-end Decay in Pears. Treating Anjou pears in water at 130° F. for 3 minutes reduced stem decay but caused severe injury. There were 4 times as many colonies of P. expansum in cultures from the stems of pears run over the line in a commercial packinghouse as in those from fruit that had not

gone over the line. This suggests that much of the contamination occurs during packing operations. Four fungicides were tested for control of stem decay. Thiabendazole (1000 ppm) and captan at 1200 ppm reduced infection but did not provide adequate control. (MQ 2-124)

2. California Grapes. After 5½ months' storage at 32° F. Emperor grapes that were hydrocooled with 38° F. water and fumigated with SO₂ for 2 minutes were cleaner, brighter, and had more attractive stems than those that were cooled in air and fumigated with 1% SO₂ for 20 minutes. The incidence of decay was low in all lots. (MQ 2-101)

3. Composition as Related to Decay in Blueberries. Blueberries from selections high in acid developed about one-third as much decay as fruit from selections low in acid. No obvious differences in decay were associated with sugar content. Wolcott and Jersey varieties of blueberries with high anthocyanin content developed more decay than those with smaller amounts. (MQ 2-94)

4. Decay Control for Strawberries. Exposure of strawberries to temperatures between 105° and 108° F. for 45 minutes with air flows above 4 cfm/lb of fruit reduced decay by about 80% when the berries were held subsequently for 3 days. Careful control of air flow, as well as temperature and exposure time, is necessary to control decay uniformly. (MQ 2-83)

5. Heat Treatment of Peaches. Dips of 30 seconds in 0.5% tutane (2-amino-butane) reduced brown rot in inoculated peaches as effectively as hot water or hot air treatments. They were not as effective for rhizopus decay control. Similar dips in 0.5% potassium azide reduced both brown rot and rhizopus about 50%. The gas, isomaltol, was ineffective against both decays and caused fruit injury. Two and one half minute dips in 125° F. water or 30 minute exposure to 125° air of 90% relative humidity reduced both decays about 80%. Exposure to 125° air of 50% relative humidity did not reduce either decay appreciably. Germination of swollen monilinia and rhizopus spores and growth from germinated spores in heated broth was prevented at temperatures and exposure times which did not affect the germination of dormant spores. With very short exposures in heated broth extreme variation occurs in the percentage of spores surviving the treatment. (MQ 2-104)

6. Heat Treatment of Figs. Black Mission figs were heated to about 115° F. for 30 to 60 minutes at air flows ranging from 25 to 32 cfm/lb of fruit. In all combinations tested so far surface molds were reduced by about 80% during 5 days at 64°. No change in flavor could be detected in taste tests. Heating Kadota figs for 30 minutes at 118° reduced surface mold by about 70% and almost eliminated rhizopus decay. Souring was not affected. (MQ 2-114)

7. Ozone Treatment of Fruits. Ozone treatment (0.5 ppm) during storage at 35° F. had no influence on subsequent shelf life of peaches, strawberries, or blueberries held in air for 4 days at 70°. The size of fungal nests was somewhat reduced in peaches and strawberries held in ozone at 60° but low temperature was a more effective control. Ozone had no effect on decay of cantaloups held for 7 days with 0.5 ppm ozone at 45° followed by 5 days at 60°. Ozone inhibited surface mold growth but did not reduce botrytis rot on grapes during 6 to 7 days at 60° in 0.5 ppm ozone. (MQ 2-102)

8. Effects of Atmosphere Modification on Growth of Certain Fungi. Atmospheres containing only 0.25% oxygen reduced spore germination in descending order of Rhizopus stolonifer, Cladosporium herbarium, Alternaria tenuis, and Botrytis cinerea. While Rhizopus spores were most sensitive to low oxygen its mycelia grew better under lower oxygen tensions than mycelia of the other fungi. Growth of Rhizopus on inoculated strawberries in atmospheres of 21, 1, 0.5, 0.25 and zero percent oxygen decreased linearly with decreasing oxygen concentration. Growth in 1% O₂ averaged 50% of that in normal air. In 0% oxygen, although no growth occurred, there was softening of tissues around the infected area. Crude extracts of infected berries contained pectic-degrading enzymes polygalacturonase (PG) and pectin methylesterase (PME) as well as cellulase. Activities of these enzymes were directly related to the amount of growth of the fungus in each atmosphere. Rhizopus grew and produced enzymes under near-anaerobic conditions on glucose medium but not on pectin medium. In the latter, production was repressed by addition of glucose to the medium. Carbon dioxide, when added to low-oxygen atmospheres, further depressed the growth of Rhizopus stolonifer. (MQ 2-112)

9. Enzyme Relationships in Penicillium Strains. On a defined medium with different sources of organic carbon, virulent and avirulent strains of Penicillium expansum, P. digitatum and P. italicum produced endo- and exopolygalacturonase but no detectable pectin methylesterase or pectin lyase. Extracts from oranges infected with P. italicum or P. digitatum and from apples with P. expansum also contained the polygalacturonases. Extracts from sound fruits did not contain polygalacturonases. In vertical starch-gel zone electrophoresis of culture filtrates and diseased tissue extracts, the number, location, electrophoretic mobility, and relative activity at sites of endo- or exopolygalacturonase activity depended on the fungus species, virulence of the strain, organic carbon source, and gel pH. (MQ 2-96)

10. Proteolytic Enzyme Activity by Fungi. Botryosphaeria ribis (and 10 other fungi, in appropriate hosts) produced protease in infected apples. Because enzymes are often inactivated by host polyphenols a method is being developed to vacuum-infiltrate a solution of polyethylene glycol into diseased B. ribis-apple tissue to inactivate polyphenols and increase enzyme recovery. (MQ 2-97)

11. Fungicides for Control of Decay in Apples and Pears. Delicious, Rome, and Winesap apples were treated with dips of sodium-o-phenylphenate (SOPP), 2-aminobutane (2AB), diphenylamine (DPA) and a mixture of 2AB and DPA. SOPP was

most effective in controlling decay followed in order by 2AB + DPA, 2AB, and DPA. On Golden Delicious the treatments containing DPA were less acceptable than on the other varieties due to chemical injury caused by DPA. Anjou pears stored for 7 months in polyethylene box liners had the most decay when treated with SOPP and the least decay with captan dip. Germination of rhizopus spores soaked for 1 hour in 0.5 percent SOPP was only slightly inhibited if the spores were rinsed with clear water after treatment. (MQ 2-125)

12. Effects of Vapor Heat on Fungus Spores. Ungerminated spores of 4 decay causing fungi were treated with moisture-saturated hot air at 110° F. under the same conditions used for heat treating flowers and strawberries. Times required to kill half the spores (LD₅₀) were 68 minutes for Alternaria tenuis, 33 minutes for Rhizopus stolonifer, 16 minutes for Botrytis cinerea, and 12.5 minutes for Cladosporium herbarium. If Botrytis spores were suspended in water for 6 hours prior to treatment to induce germination, survival was reduced 50% (Exploratory)

13. Market Losses in Apples. In the New York City market, losses in Eastern and Western Red Delicious apples was slightly less than 1% at wholesale, about the same at retail and about 2.5% at the consumer level. Losses averaged somewhat higher at wholesale and retail markets but lower in consumer channels in Chicago. Losses were principally from internal breakdown, bruises, and decay. (MQ 2-132)

14. Market Losses in Peaches. Total losses in peaches in the market averaged about 14% in both New York City and Chicago. Losses at the consumer level were generally greatest. Most of the wastage resulted from development of brown rot as the fruit ripened. (MQ 2-132)

15. Market Losses in California Strawberries. Total market losses were rather high (average about 45%) with losses increasing at each step from wholesale to the consumer. Most of the losses were due to decay. (MQ 2-132)

F. Prevention of insect infestation

1. Biological Control. Pathogens in stored-product insects have received very little attention until new studies were initiated during this reporting period. Many species of protozoan pathogens have been found in a variety of stored-product insects from laboratory cultures and field collections. Most of them have not been reported previously from stored-product insects and represent undescribed species. A granulosis virus was isolated from two laboratory cultures of the Indian-meal moth. Several field populations of this moth were found infected with Bacillus thuringiensis. All the pathogens found were readily transmitted perorally. All but one were highly pathogenic. Larvae that acquired acute infections died before pupating. Laboratory cultures of insects infected with many of these pathogens have been established for future studies.

The morphology and developmental cycle were described for a previously unknown species of Nosema from the Indian-meal moth. The pathogen was found to invade a variety of tissues and organs. Larvae were readily infected perorally and those with acute infections usually died before pupating. The pathogen invaded developing eggs. Adults harboring latent infections transmitted the pathogen through eggs. Tests with other species of insects indicate a limited host specificity. A manuscript describing the new species of pathogen and the related findings has been sent to a journal for publication. (Exploratory)

2. Biology and Ecology. It was discovered that many infestations believed to be the saw-toothed grain beetle, Oryzaephilus surinamensis (L.) are actually the closely related merchant beetle, O. mercator (Fauvel). This raises many questions that need to be answered about comparative biology, ecology, habits, behavior, nutritional requirements, and food preferences. In comparative studies of the two species under constant conditions of 86° F., 50% relative humidity and low light intensity, each developed best on rolled oats plus yeast, next best on almonds, and rather poorly on raisins. Neither species did well on prunes where only a few saw-toothed grain beetles completed development from egg to adult and none of the merchant beetles developed to the pupal stage. The saw-toothed grain beetle did better on raisins than did the merchant grain beetle, and the latter did better on almonds. Records are being accumulated on temperature and humidity ranges in several storage areas for dried fruits and tree nuts, and in the stored commodities. This information will serve as a foundation for future ecological studies. (Exploratory)

Adult females of some species of the dermestid genus Trogoderma are extremely difficult to identify. To discover new identification characters, 7 species were cultured and specimens of 9 others were obtained for study. About 700 slides were prepared for study of internal characters and some 600 adults were pinned. The significant discovery of a character to identify female khapra beetles was published. It was also found that the shape and size of internal structures of the female reproductive system permit identification of other species. Drawings are being made and this information will be published after further study. A manuscript has been written to describe the technique for slide preparation. A series of color photographs has been made to show the elytral color patterns of the various species. (Coop. Agreement, California Department of Agriculture)

A comparison of the digestive enzymes, development, and egg laying of four species of mites has helped to explain their food requirements. Acarus siro fed and developed on the hyphae of many species of molds but fecundity was usually low. It digested starch very poorly and was adapted to foods rich in fats. This was reflected by low amylase and high lipase recoveries from the mites. A. farris digested starch and fat only in small amounts but fed much better on microorganisms as a single food. Tyrophagus putrescentiae readily fed on all microorganisms tested, with high fecundity and low mortality. It also digested starch rather well. Rhizoglyphus echinopus fed on many microorganisms but fecundity was low and it digested neither starch nor fat very well. (E21-MQ-1(a))

Studies thus far indicate hypopus formation is more related to population density and kind of food than to temperature or humidity. Appearance of hypopi is more common in some populations than in others of the same species. Humidity affects the transformation of hypopi to tritonymphs. Histological and anatomical studies of hypopi of Acarus farris show this is not a regressive stage. It is anatomically and functionally adapted to survive unfavorable conditions and to disseminate the species. It has a thick cuticle to resist drying out and has a special complex of muscles for the sucking disc and dorsal side of the body, enabling it to attach to other animals or moving objects. There is a striking difference in the alimentary canal, where the pharynx, esophagus, and stomach are small. The walls of the stomach resemble those of the esophagus, side protuberances are small, and anterior glands are absent (E21-MQ-1(a))

3. Improved Pesticidal Control. Results of small scale tests with malathion spray and dust treatments for one year on figs and two years on raisins indicate that 5 to 20 ppm in dust form and 50 ppm as a spray show sufficient promise to carry them into larger scale tests. (MQ 1-15)

Equipment for applying protective sprays to grain is not suitable for treating dried fruits or tree nuts. A new machine was designed, constructed, and tested. It can be adjusted to apply a wide range of dosages, fits in with industrial handling conditions, and appears to perform satisfactorily. Shelled almonds were treated with this machine at 3, 8, 12, and 16 ppm for a small-bin storage test. Treated almonds subjected to taste panel tests showed no significant change in flavor or odor. A preliminary test indicates that blanching to remove the seed coat eliminates a large amount of the malathion residue. In another small-bin test malathion as a dust at 10 and 20 ppm and as a spray at 30 and 50 ppm gave good protection through 1 year of storage. (MQ 1-27)

The vapor generator developed by the Savannah laboratory for dispensing dichlorvos was operated August through October, the period when vinegar flies and dried fruit beetles are most numerous, in a wine cellar with 268,495 cu. ft. of air space. High humidity rapidly decreased vapor concentrations but the degree of control was promising. A single exploratory test was made to compare the rate of decrease in air concentration of dichlorvos after a vapor generator treatment and a thermal aerosol treatment. After one-half hour, there was a 10% loss from the vapor treatment and 80% from the aerosol, and at the end of an hour the losses were 52% and 90% respectively. Samples of sherry and tokay wines exposed in open beakers to 3 hours of vapor generator operation contained less than 0.03 ppm of dichlorvos. A taste panel could detect no off flavor. (MQ 1-34)

A psocid as yet unidentified was found to cause high mortality of the Indian-meal moth in a laboratory room at Fresno. It consumed eggs and fed some on dead larvae but live 1st instar larvae were not eaten.

A study has begun to determine the effect of various concentrations of malathion on the oviposition cycle of the Indian-meal moth. At one concentration the peak of oviposition occurred at 9 p.m. Pacific Standard Time for both treated and untreated moths. Treated moths laid more eggs the first day than did untreated ones but the viability was low. Treated moths produced fewer eggs and offspring than did untreated moths. When last instar larvae were treated with malathion, swelling of the thorax and abdomen was observed in some and an occasional dead larva was found to have adult as well as larval characteristics. This information was given to an insect physiologist at the Savannah laboratory for further investigation. (Exploratory)

About 10 million malathion-treated paper raisin drying trays were used by industry for the 1966 crop, the first year they were commercially available. The trays were to have been treated with 100 mg. of malathion per sq. ft. They contained an average of 60 mg./sq. ft. when placed in the vineyards. Raisins dried on the trays contained about 3.5 ppm of malathion, well within the 8 ppm tolerance and enough to protect the raisins against insects during storage prior to processing. The industry was enthusiastic about the performance of the trays. There are plans to have 22-24 million trays available for the 1967 crop. (MQ 1-34)

4. Insect-Resistant Packaging. Some tests are completed and others have been in progress at least 3 months to evaluate the insect resistance of packages in current use for raisins, figs, prunes, peaches, apricots, and mixed dried fruits. The 941 packages in the tests comprise 19 series of cartons and 17 series of visipacks or flexible pouches. They are exposed in a laboratory storage room to a heavy infestation of several species of insects that attack dried fruits. A plastic cup with heavy polyethylene cover, a package not used extensively, was the only type not infested after 6 months in the exposure room. All other types of packages were at least 33% infested within 3 months. Insects attacked the packaged raisins and figs more than the other fruits. The most resistant of the cartons were those with a foil overwrap. The best of the pouches was a polypropylene-cellophane combination. The heavier polyethylene-cellophane combinations provided some insect resistance. In another series of tests lasting 12 months, plain kraft board gave an average of 2.2 months of protection against infestation, board plus 1-mil polyurethane 3.8, board plus 1-mil nylon 5.2, board plus 1-mil polyethylene 6.2, and board plus 1-mil polycarbonate 6.4. A laminate of 0.0035 foil between two layers of 1-mil polyethylene gave complete protection in all 5 replicates. (MQ 1-22)

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VEGETABLES

Market Quality Research Division, ARS

Problem. Most fresh vegetables are highly perishable. Research is needed on sources of inoculum and time of infection and physical and chemical methods for decay reduction. Basic studies are needed on cell metabolism as related to the causes and control of functional disorders and the nature of ripening and aging. Product quality as related to mechanical harvesting will need increasing study as will the effects of storage environment on keeping and eating quality. Safe and effective transportation can be accomplished only by continued research with transportation services, equipment, and methods as these affect ultimate quality of the product in the market. The increasing interest in liquid gases for transit refrigeration and atmosphere modification and mechanical refrigeration with and without atmosphere modification has posed a series of new problems relating to effects on the commodities from use of substantial amounts of nitrogen or accumulation of carbon dioxide in the load compartments. Additional information is needed on objective indices for harvest maturity and quality factors as related to standardization and grading, and practical measurements for quality changes as the product moves through marketing channels.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of applied and basic research relating to quality measurement and protection of vegetables as they pass through the marketing channels. The work is conducted by horticulturists, plant pathologists, plant physiologists, and food technologists.

Research is conducted at USDA laboratories in Beltsville, Md.; Fresno, Calif.; Orlando, Fla.; Belle Mead, N. J.; Chicago, Ill.; and Harlingen, Texas, and at the North Carolina Agricultural Experiment Station, Raleigh, N. C.

Projects terminated during this period included: Detection and description of freezing injury (MQ 2-29), Effects of high nitrogen on vegetables during simulated transit (MQ 2-71), Chilling injury on eggplant (MQ 2-86), Storage of asparagus crowns (MQ 2-89), Ozone on vegetables (MQ 2-102), and Relation of fresh product factors to processed quality in sweetpotatoes (MQ 3-50).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 19.9 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Separation of Undercolor Tomatoes. Because "undercolor" tomatoes may affect the flavor of strained products but not the color, a prototype device was constructed to sort "undercolor" tomatoes from fruit used for juice manufacture. Tomatoes are sorted as acceptable or non-acceptable color by a device which measures the natural chemiluminescence of the fruit. The response is temperature dependent and electronic adjustment must be made for fruit temperature. The development of this instrument will make tomato inspection more objective and when used in-plant will overcome problems of trim-line color sorting. (Coop. Agreement with Campbell Soup Co.)
2. Maturity Separation of "Mature-Green" Tomatoes. In limited preliminary studies, mature-green tomatoes of HCl46 variety gave absorption peak of 585 nm on the Biospect. Similar green-color tomatoes which were immature did not show this peak and had not formed gel in the locules, which is a primary criterion for maturity. Mature-green tomatoes initially sorted with the Difference Meter (Δ O.D. 570- 580 nm), ripened after 7 days at 70° F., were closely related (low to high values) to visual judgment of color change (green to red color). Tomatoes ripened at 70° F. under continuous 40 W cool white fluorescent light were redder both internally and externally than tomatoes ripened in subdued light. (Exploratory)

B. Quality maintenance in handling and packaging

1. Types and Effectiveness of Lettuce Wraps. Decay increased in all film-wrapped, inoculated lettuce when the ambient humidity was increased from 50 to 70 and 90 percent. Less moisture loss but more decay developed in lots wrapped in the non-perforated polystyrene and minutely perforated polyvinyl chloride A than in lots wrapped in vented cellophane or the more permeable films. Lettuce wrapped with non-shrunk polystyrene and polyvinyl chloride (b) had more marketable heads when held at low humidity than shrunk film-wrapped heads or the perforated film-wrapped lettuce. At higher humidities the perforated film-wrapped lots had less decay and more marketable heads generally than others. (MQ 2-80)
2. Origin-wrapped vs. Non-wrapped Lettuce. Quality differences between naked-packed and origin-wrapped California lettuce generally was slight in simulated shipping tests made in the laboratory and also in actual shipping tests to the east coast. Crushing and bruising were more prevalent in naked-packed lettuce than in origin-wrapped lettuce in the holding tests at the laboratory, but not in the actual shipping tests. Butt discoloration was slightly more severe in the naked-packed than in the origin-wrapped lettuce in lots examined at the laboratory and also in the lots examined on the east coast after 4 days at 50° F. (MQ 2-80)

C. Quality maintenance in storage

1. Intercellular Space in Sweetpotatoes. Intercellular space of four varieties of sweetpotatoes differed between varieties at harvest but in individual varieties it varied less than 1.5 ml. per 100 ml. of root volume at three harvest dates and three locations. Intercellular space in each variety at harvest differed little this season from the previous season. Large differences in weight losses and volume losses developed in roots of 10 commercial varieties of sweetpotatoes due to differences in development of intercellular space and pithiness. The largest amounts of intercellular space developed with rapid weight losses, small volume losses, low tissue specific gravities, and high respiration rates. An estimating equation capable of predicting intercellular space to within one ml. per 100 ml. of volume was developed. (MQ 2-128)

2. Sprout Inhibitors for Sweetpotatoes. A high rate of CIPC applied in fog form to stored sweetpotatoes, (30 ppm residue) reduced sprouting about 80 percent, and a low rate (10 ppm) reduced sprouting about 40 percent during about 6 months' storage. Roots removed after treatment contained less than 15 ppm CIPC residue in the most exposed location receiving the highest application.

In other storage tests 5 percent CIPC dust was applied to roots in the top layer of field boxes stacked 4 or 5 layers high on pallets as they were removed from the curing room and to the storage room. Dust was applied to provide the equivalent of 30 or 10 ppm CIPC residue to the roots. At desirable storage temperatures CIPC dust applied over the palletloads of sweetpotatoes as they were placed in storage reduced sprouting by 50 to 75 percent. Where storage temperature was not controlled as well, nontreated roots developed noticeable amounts of sprouts in the top of the stacks and treatment with dust at 10 ppm reduced sprouting very little except where dust concentration was greatest. (MQ 2-130)

3. CA Storage of Cauliflower. Undesirable darkening and softening in cooked cauliflower induced by prior holding in CO₂-enriched atmospheres is related to pH changes in the tissue. A rise in pH of 1.2 units, caused by high CO₂ in the atmosphere, was accompanied by significant increases in discoloration and softening. Aeration for 24 hours before cooking, and cooking the curds in acidified water eliminated the adverse effects of high CO₂.

The flavor of cooked cauliflower was affected adversely by prior storage for 4, 8, or 15 days at 41° F. in low O₂ atmospheres ($\frac{1}{4}$ to 2%). The off-flavors persisted when the heads were cooked after an additional 3 days in air at 50°. Visible injury resulted when the heads were stored 8 days at 41° in $\frac{1}{4}$ or $\frac{1}{2}$ % O₂. The flavor of heads stored in 5% O₂ was about equal to that of heads stored in air throughout. Shear resistance of the curd was not affected by low O₂ but the curd yellowed slightly during storage, especially in $\frac{1}{4}$ % O₂. Soft rot affected almost all heads held 8 or 16 days in $\frac{1}{2}$ or $\frac{1}{4}$ % O₂, but was negligible in samples from the other atmospheres. Cauliflower

held at 37° F. generally responded like that held at 41°. No off-flavors developed at 37° in 2% O₂. (MQ 2-123)

4. CA Storage of Radishes. Topped red radishes held at 37, 41, or 50° F. for 15 days in atmospheres with $\frac{1}{4}$, $\frac{1}{2}$, or 1% O₂ developed no top and root growth. At 50° surface mold grew on roots held in $\frac{1}{2}$ % O₂ and bacterial soft rot developed on those in $\frac{1}{4}$ or $\frac{1}{2}$ % O₂. Radishes held in 5% or 10% O₂ for 15 days did not differ appreciably from those held in air regardless of storage temperature. Pithiness, a sign of aging, was most severe at 50° F. and least severe at 37°, and its incidence was not affected by O₂ concentration. (MQ 2-123)

5. CA Storage of Broccoli. Yellowing of broccoli was slower in atmospheres containing $\frac{1}{4}$ or $\frac{1}{2}$ % O₂ than in air during 13 days at 41° or 50° F. At 37°, the effect of low O₂ on yellowing was evident only after 4 subsequent days in air at 50°. Samples held 13 days in $\frac{1}{4}$ % O₂ at 50° were as green as those held in air at 37°, while those held in air at 50° were completely yellow. The low O₂ concentrations did not induce injuries or off-flavors in broccoli at the temperatures tested. (MQ 2-123)

6. CA Storage of Texas Cantaloups. After 3 weeks at 40° F. cantaloups held in 1% oxygen were fairly bright, mostly acceptable and firm, and required several days at room temperature to soften. The effects of carbon dioxide in the atmospheres were not evident until the melons had been in 60° air for 3 days. Those that had been held previously in 1, 5, and 10% oxygen with either 5 or 10% carbon dioxide levels showed noticeably less mold growths than melons from similar oxygen levels but without carbon dioxide. (MQ 2-136)

7. CA Storage of Texas Honeydew Melons and Pineapples. Quality in honeydew melons was not benefited by storage in modified atmospheres. After 3 weeks at 45° F. melons held in 2.5, 5, and 10% oxygen were similar in appearance to those held in air. They were still comparable after an additional 6 days in 60° air. However, melons from reduced oxygen atmospheres with either 5 or 10% carbon dioxide were not acceptable because of *Alternaria* and bacterial spot decay. No benefits were obtained from modified atmospheres with the smooth Cayenne variety of pineapple in atmospheres similar to those used for honeydew melons. (MQ 2-136)

8. CA Storage of Asparagus. The quality of fresh asparagus was no better after one week in $\frac{1}{4}$, 1, or 3% oxygen atmospheres than in air at 32° or 50° F. An oxygen level of $\frac{1}{4}$ % injured the asparagus at both temperatures. One percent oxygen was injurious at 50°. After 1 week of storage, uninjured spears remained in fair condition for 5 days at 60° but almost all injured spears decayed. Only the $\frac{1}{4}$ % oxygen atmosphere reduced the respiration rate of asparagus at 32°. The over-all reduction for the 7-day storage period, as compared to air, amounted to 17%. At 50° respiration in atmospheres containing not more than 3% oxygen averaged about 30% less than in air. There was no difference in the tenderness of asparagus held one week in air and in controlled atmospheres containing 1% oxygen and zero, 5%, and 10% carbon dioxide. (MQ 2-136)

9. CA Storage of Celery. Celery held at 32° F. in 0% O₂ (100% N₂) had better color and condition than celery held in air after all storage periods and the subsequent deterioration at 68° F. in air was not hastened. At 41° F., exposure of 8 days or more resulted in damage. Oxygen concentrations between ½% and 21% (air) seemed to have very little effect at either temperature for all storage durations. Carbon dioxide, at concentrations from 5% to 20% resulted in somewhat better quality at time of removal from storage but tended to hasten deterioration after transfer to 68° F. The effect increased with CO₂ concentration. Celery stored in air at 32° F. maintained much better quality than that stored at 41° F. (MQ 2-136 Cooperative Agreement with the University of California)

D. Quality maintenance during transportation

1. Asparagus Simulated Air Shipment. Soft rot at the tips was nearly absent in asparagus after 2 days in air or in a CO₂ atmosphere gradually reduced from 22% by ½ every 7 or 19 hours. After 2 additional days in air, tip rot and soft rot at the butt end were significantly higher in spears held in air than in those held in CO₂. Tips that were open with buds visible or with actual feathering, had over twice the incidence of soft rot as tightly closed tips. (MQ 2-136)

2. Containerized Export Shipments. Irregular and slow cooling in the top-iced load of non-hydrocooled, prepackaged carrots in a mechanically refrigerated van, emphasized the need for precooling for a long haul to an overseas market. The degree of cooling obtainable within minutes by hydrocooling required 76 hours in one location in the carrot load. Vacuum cooling of the leafy vegetables in the mixed vegetable load plus 6,000 pounds of top ice reduced product temperatures to 42° to 43° F., which was maintained during most of the transit period by the van refrigeration unit. (MQ 2-139)

3. Load Patterns for Lettuce Shipment. Average load temperatures in mechanically refrigerated rail cars and trailers on flat cars (TOFC) were not appreciably affected by load pattern. But air circulation in both cars and trailers was improved by the bonded-block load pattern, as indicated by the more uniform temperatures in these loads than in the solid loads. Because of improved air circulation in the bonded-block loads, temperature variation was generally 2° or 3° F. less than in the solid loads. However, damage to the lettuce and container from crushing was greater in the bonded-block load than in the conventional solid load and less cartons could be loaded than in the solid load. (MQ 2-84)

4. Standing Test With Mechanically Refrigerated Rail Car and Van. Lettuce temperatures averaged 36° F. in a 50-foot mechanically refrigerated rail car and 37° in a piggyback trailer when the thermostats were set at 34° F. during a simulated transcontinental transit period. The difference between the warmest and coolest positions in the loads was 5° in the car and 6° in the trailer. Carbon dioxide in the atmosphere of the car had increased to 7.2 percent by the ninth day, but in the trailer the carbon dioxide level did not exceed 2.7 percent. Relative humidity was high (91 to 97 percent) in the car

and trailer. At unloading lettuce that had been maintained at 35° to 37° F. was rated "excellent" but that maintained at 38° or 39° was rated "good." (MQ 2-84)

E. Postharvest physiology

1. Ethylene Production by Lettuce. Studies were conducted to elucidate the relationship of temperature to ethylene production and russet spotting. Lettuce previously held for 4 days at 59° F. produced ethylene at a rate of 35×10^{-6} ml/kg-hr after 5 hours at 70° F; that held at 41° F. for 4 days produced 28×10^{-6} ml/kg-hr after 24 hours at 70°; and lettuce held at 32° F. for 5 days produced 50×10^{-6} ml/kg after 76 hours at 70°. (Exploratory)

2. Russet Spotting of Lettuce. Symptom-free lettuce from obviously mosaic infected areas of commercially planted fields had more than twice the number of heads affected by slight to severe russet spotting after 7 days' storage at 41° F. than lettuce from nearly virus-free areas of the same fields. After an additional 4 days at 50°, the proportion of moderate or severe russet spotting was similar. (Exploratory)

F. Postharvest disease control

1. Neck Rot in Onions. After 4 months in common storage, Ortho 5871 - 80 WP and Chemagro 50 WP gave good control of botrytis neck rot when dusted on freshly cut neck of onions. The controls developed 75% decay. Top killers were not effective for control of botrytis neck rot. Heat applied to the cut surfaces by flame or hot plate reduced neck rot decay in inoculated onions during 4 months in common storage. The reduction of neck rot with a commercial forced, heated air drier shows promise. (MQ 2-95)

2. Soft Rot in Bell Peppers. Hot water treatment of bell peppers, when used at 136° F. for 30 seconds provided good to excellent control of soft rot in commercial shipments. The effectiveness of the commercial hot water treatment was reduced by subsequent waxing of the pods. Considerable interest in hydro-heating peppers continues in Texas and additional commercial installations are planned. (MQ 2-133)

3. Enzyme Activity in Rhizopus-rotted Sweetpotatoes. No lipolytic and low proteolytic enzyme activity was detected in juice expressed from rhizopus-rotted sweetpotato. Procedures used to purify the enzymes give preparations of these unstable materials that had little or no activity. Nitrate salts are more effective than chloride, sulfate, and phosphate salts in inhibiting maceration of sweetpotato tissue by crude pectolytic enzyme from rhizopus-rotted sweetpotato. Potassium nitrite and potassium azide were as effective as potassium nitrate at 0.5 M concentration and pH 5.5. Under the same conditions, hydroxylamine had no effect. (MQ 2-129)

4. Heat Treatment of Texas Cantaloups. Cantaloups from 4 packing sheds in the Rio Grande Valley which used hot water treatments were evaluated after

6 days at 60° F. All untreated melons were unsalable at the end of the holding period, while those dipped in water at 140° for 20 to 30 seconds showed only slight surface mold at the stem scar. Controlled tests in the laboratory and commercial equipment gave similar results. The addition of 0.15% SOPP to the hot water did not increase its effectiveness. Chlorine solutions were not effective. (MQ 2-134)

5. Effects of Chlorine on a Vegetable Decay Organism. The detergent surfactants, alkyl aryl sulfonate (Santomerse), coco trimethyl ammonium chloride (Aliquot 21), and sodium tetradecyl sulfate (Tergitol Anionic 4) were effective in increasing fungicidal activity of calcium hypochlorite in vitro against Alternaria tenuis spores. Only Santomerse has been approved for post-harvest application. Mature green tomatoes washed in field equipment containing sodium hypochlorite and Santomerse had less bacterial necrosis and soft rot than tomatoes washed without disinfectants. Sodium hypochlorite alone was ineffective in reducing tomato bacterial decay. The hypochlorite-Santomerse mixture was also effective in reducing soft rot of carrots. (MQ 2-116)

6. Market Diseases of Puerto Rican Vegetables. The following commodities have been investigated for market disorders as they arrive on the Chicago market: apio (6), boniato (2), calabaza (6), ñame (17), yautia (9), and yuca (4). The figure in parentheses indicates the number of different organisms isolated from the diseased areas of the commodity. The predominant organisms are Alternaria, Cladosporium, Fusarium, Penicillia, Rhizopus, and bacteria. Re-inoculation studies indicate most of the organisms repeatedly isolated from decayed areas are pathogenic. (MQ 2-131)

7. Market Losses in Lettuce. In the New York City market average loss in head lettuce at wholesale was about 3%; retail losses averaged about 6% and wastage at the consumer level was almost 9%. About 2/3 of the total loss was due to decay with the remainder caused by bruising and rib breakage. Total loss was about the same in the Chicago market but less of the loss occurred at retail and more at the consumer level. (MQ 2-132)

8. Identification of Market Diseases. New symptoms of black leaf speck were seen on cabbages received from Florida. In addition to the typical black specking of the leaves, many major and minor veins throughout the head had a grayish-blue water-soaked appearance. In some instances the discoloration was local, in others it extended over a considerable portion of the vein. This aspect of black leaf speck is related to high copper content of soils in the Sanford area of Florida. Symptoms usually did not appear until cabbages are held at low temperatures.

Geotrichum candidum, the fungus causing sour rot, was isolated from practically every sample (15) of carrots observed, regardless of where they have been grown or their condition. (MQ 2-64)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance During Handling and Packaging

Hardenburg, R. E. 1966. Packaging and protection. U. S. Dept. Agr. Yearbook of Agriculture on Protecting Our Food Supply, Chap. 12, pp. 102-117. (MQ 2)

Hruschka, H. W. 1966. Storage and shelf life of packaged rhubarb. U. S. Dept. Agr., Marketing Research Report No. 771. (MQ 2-61)

Stewart, J. K., M. J. Ceponis, and C. M. Harris. 1967. Market quality of film-wrapped and naked-packed head lettuce. U. S. Dept. Agr. ARS 51-11. (MQ 2-84)

Quality Maintenance During Storage

Hoover, M. W. and L. J. Kushman. 1966. Influence of raw product storage treatments on the quality of sweet potato flakes. Amer. Soc. Hort. Sci. Proc. 88:501-506. (MQ 2-73)

Kushman, L. J., D. T. Pope and R. J. Monroe. 1966. Estimation of inter-cellular space and specific gravity of five varieties of sweet potatoes. N. C. Agr. Expt. Sta. Tech. Bul. 175. (MQ 2-128)

Kushman, L. J., D. T. Pope and J. A. Warren. 1967. A rapid method of estimating dry matter content of sweet potatoes. (Abstr.) Southern Agr. Workers Proc. 64:240. (MQ 2-128)

Parsons, C. S. 1966. Freezing injury of vegetables. (Abstr.) 17th Int. Hort. Cong. Proc. 1:528. (MQ 2-29)

Pope, D. T., L. J. Kushman and J. A. Warren. 1967. The consistency of inter-cellular space at harvest in four varieties of sweet potatoes. (Abstr.) Southern Agr. Workers Proc. 64:240-241. (MQ 2-128)

Worthington, J. T. and W. L. Smith, Jr. 1966. Effect of root trimming and storage containers on field survival and yield of asparagus plants. Amer. Soc. Hort. Sci. Proc. 89:346-349. (MQ 2-89)

Wright, F. S., W. E. Splinter and L. J. Kushman. 1967. The influence of variety, time from harvest, and storage conditions on the mechanical behavior of the sweet potato. (Abstr.) Southern Agr. Workers Proc. 64:47-48. (MQ 2-128)

Quality Maintenance During Transportation

Breakiron, Philip L., C. L. Nocolos, J. K. Stewart and R. S. Kurtenacker. 1967. Reducing transport damage in top-iced shipments of fresh vegetables in bushel baskets. (A study of rail shipments of fresh peas). USDA Marketing Research Report 772. (MQ 2-84)

- Lipton, W. J. 1967. Market quality and rate of respiration of head lettuce held in low-oxygen atmospheres. U. S. Dept. Agr. Marketing Research Report 777. (MQ 2-84)
- Stewart, J. K. 1966. Liquid nitrogen refrigeration--its effect on transit temperatures and quality of lettuce. Proc. Handling Perishable Agricultural Commodities. 20:98-111. (MQ 2-84)
- Stewart, J. K., M. J. Ceponis, and C. L. Burton. 1967. Effect of load pattern on transit temperatures and crushing of lettuce in transcontinental shipments. USDA, ARS 51-12. (MQ 2-84)
- Stewart, J. K., J. M. Harvey, M. J. Ceponis, and W. R. Wright. 1966. Nitrogen--its effect on transit temperatures and market quality of western lettuce shipped in piggyback trailers. USDA Marketing Research Report 759. (MQ 2-84)

Postharvest Disease Control

- Mallison, E. D. and D. H. Spalding. 1966. Use of ozone in tomato ripening rooms. USDA, ARS 52-17. (MQ 2-102)
- McColloch, L. P. 1966. Chilling injury of eggplant fruits. USDA, Marketing Research Report 749. (MQ 2-86)
- McColloch, L. P. and W. R. Wright. 1966. Botrytis rot of bell peppers. USDA, Marketing Research Report 754. (MQ 2-52)
- Segall, R. H. 1967. Bacterial soft rot, bacterial necrosis, and alternaria rot of tomatoes as influenced by field washing and postharvest chilling. Plant Disease Reporter 51:151-152. (MQ 2-116)
- Segall, R. H., and N. C. Hayslip. 1966. Susceptibility of Manapal and Grothen's Globe tomatoes to alternaria rot. Proc. Fla. State Hort. Soc. 79:227-229. (MQ 2-88)
- Smith, M. A., L. P. McColloch and B. A. Friedman. 1966. Market diseases of asparagus, onions, beans, peas, carrots, celery, and related vegetables. USDA, Agriculture Handbook 303. (MQ 2-64)
- Spalding, D. H. 1966. Toxic action of Rhizopus stolonifer in sweetpotato tissue. (Abstr.) Phytopathology 56:902. (MQ 2-129)

POTATOES

Market Quality Research Division, ARS

Problem. The increased demand for potatoes to be used for chips, frozen french fries and other processed forms has created special problems of preventing undesirable chemical changes due to low temperatures during storage and transport. The use of higher temperatures has brought on additional problems of moisture loss, internal black spot, and of bacterial and fungal decay. Higher temperature storage also calls for control of sprouting, with increased emphasis on sprout inhibitors. Objective indices are needed to identify quality factors that are important for specific product usage and relate measurable characters of the raw product to quality of the processed product. Also needed are instruments for non-destructive detection and rejection of potatoes with internal disorders during grading.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving horticulturists, plant pathologists and plant physiologists engaged in applied and basic research. The work at East Grand Forks, Minnesota, is conducted in cooperation with the Minnesota and North Dakota Agricultural Experiment Stations and the Red River Valley Potato Growers Association. The work at Presque Isle, Maine, is in cooperation with the Maine Agricultural Experiment Station. Research on transportation of early potatoes for chips and modified atmospheres is conducted by the Fresno, California station. The studies at Beltsville involve quality evaluation, storage environments, and basic research. Studies on market diseases are conducted at Chicago and Belle Mead, New Jersey.

The Federal effort devoted to research in this area totals 5.0 scientist man-years. Of this number 0.5 is devoted to quality evaluation; 0.7 to quality maintenance in handling and packaging; 1.7 to quality maintenance in storage; 0.9 to quality maintenance during transportation; and 1.2 to post-harvest disease control.

Projects terminated during this period included: Transit temperatures of California potatoes (MQ 2-55) and Storage temperatures for processing potatoes (MQ 2-69)

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 7.0 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Color Measurement in Potato Chips. Potato chips, ranging in color from very light yellow to very dark brown, were measured objectively with 3 different instruments and subjectively by several observers. The results indicate that potato chip color can be satisfactorily measured with a variety of instruments. Correlation coefficients between many color parameters of potato chips and panel scores were highly significant, and exceeded that required for prediction purposes. The Photovolt Reflection Meter with tristimulus green filter is the most economical of the instruments used. For more precise measurements, fluorescent and light scattering need to be evaluated. (MQ 3-97)

2. Susceptibility of Tubers to Bruising. Results of tests indicate a linear dependence of the elasticity of potato tissue on turgor pressure within the potato. The basis for a rapid measurement of turgor pressure differences within potatoes was provided by determining the elasticity with a device measuring sound vibrations within the tissue. Mechanical bruising and turgidity were significantly and directly correlated. Irrigation prior to harvest increased turgidity while root pruning decreased turgidity within the tubers. Vine removal 4 days before harvest did not significantly influence turgidity at harvest. (MQ 3-40)

B. Quality maintenance in handling and packaging

1. Stone Separation by Water. Potatoes of the Russet Burbank and Kennebec varieties that were subjected to a water flume-stone trap before storage in pallet boxes at 45° and 55° F. showed no injury to tuber quality after 5 months' storage. Flumed seed potatoes shipped by rail to northern West Virginia arrived in excellent condition except for some freezing damage incurred during transit.

Seed potatoes, pre-cut in January after washing and chemical or heat treatments, averaged 97% stand as compared with 75% stand for seed planted immediately after cutting. The increased stand from pre-cut seed was due to control of black-leg and seed-piece rots. Potatoes of two varieties, Russet Burbank and Kennebec, remained in excellent condition for 2 months after being pre-cut, treated with Polyram dust, and stored in bulk bins before planting. (MQ 2-93)

C. Quality maintenance in storage

1. Effect of Periods and Rates of Ventilation on Quality of Maine Potatoes. Intermittent forced-air ventilation of potatoes stored in bulk bins at 55° F. for processing effectively controlled Fusarium tuber-rot and soft rot. Pressure bruising was increased in the ventilated bins. When ventilated 12% of the storage period, the amount of pressure bruising was doubled over the non-ventilated control. Approximately four times as much pressure bruising

occurred in bins with forced air ventilation for 25% and 50% of the storage period as in the non-ventilated check. Ventilation at approximately 3 cfm/cwt. dried up artificially induced field frost injury in bulk bin storage in about 2 months.

No internal defects and very little surface mold developed on Katahdin or Kennebec potatoes when storage at 32° F. was interrupted by periods of one week at 60° so that the longest continuous time at 32° was 3 weeks. After 19 weeks, tubers at 32° with 60° interruptions were comparable in internal and external appearance to tubers stored continuously at 36° or 40°. Respiration rates measured at 60° F. one day after removal of tubers from storage, were about $\frac{1}{2}$ as high for those shifted from 32° to 60° periodically as for tubers at 32° continuously. Respiration rates were similar for shifted tubers and those at 36° or 40° continuously. Total and reducing sugar content of the shifted tubers followed a pattern similar to respiration rates.

Before storage, cut surfaces of tubers had a bluish-white fluorescence under ultra-violet light. After 11 weeks at 32° F. a bright yellow fluorescence often was seen in areas where mahogany browning or blackheart occurred. This type of fluorescence did not appear in tubers stored at 32° with intermittent storage at 60° or those stored at 36° and 40°. This fluorescent material is being identified. (MQ 2-92)

2. Chilling Injury. Mahogany browning and other injury symptoms shown by potatoes stored at 0° C. did not develop when the potatoes were warmed intermittently to 15.5°. Cooperative work with the Horticultural Crops Research Branch (MQ 2-92) showed that potatoes had 2.5 to 4 times as much total sugar content when held for 4 months at 0° as compared to those held intermittently at 15.5° for 1 week each month. A yellow fluorescence appeared in potatoes stored at 0°. Fluorescence emission spectra of tissue slices showed a broad spectrum with maxima at 435 and 480 mμ. Fractionation of extracts yielded some fluorescing compounds with maxima at 435 mμ and others with maxima at 480 mμ. Identification of the fluorescing compounds is being attempted.

D. Quality maintenance during transportation

1. Low Oxygen Atmospheres. Potatoes held for 8 days in $\frac{1}{2}$ or 1% O₂ at 68° or 59° F. were injured severely. Most of the tubers held in low O₂ were decayed and/or had black heart, whereas nearly all those held in air or 5% O₂ were sound. Both low O₂ atmospheres prevented periderm formation and inhibited recovery even after removal of the tubers to air. Five to 10% decay developed when the tubers held in $\frac{1}{2}$ or 1% O₂ at 41° were subsequently held for 8 days in air. (MQ 2-136)

E. Postharvest disease control

1. Hot Water Treatment of Seed Potatoes. Hot water dips severe enough to cause tuber breakdown failed to eradicate spindle tuber or leaf roll viruses in infected tubers. A 5-minute dip in 130° water was as effective as Semesan bel in controlling Rhizoctonia stem-canker and seed piece rots. The best time-temperature conditions for disease control and overall seed quality was 5 - 7 minute dips in 130° water. Tissue breakdown occurred when tubers were soaked for more than one minute at 135°. Soft rot followed and no sprouting occurred. In general, non-injurious hot water dips accelerated sprouting and resulted in early emergence and more uniform stands. In some cases, yields were increased from treated B-size seed. (MQ 2-90)

2. Market Losses in Potatoes. Maine Katahdin potatoes showed an average of 1.5% loss at wholesale in the New York City market, principally from mechanical injuries. Retail losses were very slight because almost all were sold prepackaged. Trimming losses averaged about 3.5% at the consumer level. Most of this loss was due to Fusarium rot, physiological disorders, and cuts and bruises.

In the Chicago market average losses in Red Pontiac potatoes from the Red River Valley were 3.4% at wholesale, less than 1% at retail, and slightly more than 4% at the consumer level. (MQ 2-132)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance During Handling and Packaging

Hunter, J. H. and J. B. Wilson. 1966. Some aspects of hydraulic handling of potatoes. Maine Agr. Expt. Sta. Misc. Rpt. 120. (MQ 2-93)

Johnston, E. F. and J. B. Wilson. 1966. Soil, air, and tuber temperatures and bruise resistance. Maine Agr. Expt. Sta. Misc. Rpt. 119. (MQ 2-93)

Quality Maintenance During Storage

Hruschka, H. W. and P. H. Heinze. 1967. External and internal sprouts in potatoes dipped in low concentration CIPC-water emulsions. Amer. Potato Jour. 44(2):51-55. (MQ 2-130)

Wilson, J. B. 1967. Pressure bruising and internal black spot /Maine/ Potato Councillor. (April) (MQ 2-92)

Wilson, J. B. 1966. Shrinkage of potatoes in storage and its causes. Proc. Natl. Potato Util. Conf. ARS 74-40, p. 29-37. (MQ 2-92)

Wilson, J. B. and E. F. Johnston. 1966. Salvaging field-frosted potatoes. Maine Farm Res. 14(3):31-34. (MQ 2-93)

Wilson, J. B. and R. L. Todd. 1966. Removing Chloro-IPC residues. Maine Farm Res. 14(3):54-56. (MQ 2-130)

Postharvest Physiology

Craft, C. C. 1966. Salt hardness and dye reduction by potato tissue and mitochondrial fractions as influenced by previous storage of the tubers. Plant Physiol. 41:1662-1666. (Pioneering Laboratory)

Craft, C. C. 1967. Respiration of potato tissue as influenced by previous storage temperature of the tubers. Amer. Potato Jour. 44:174-181. (Pioneering Laboratory)

Heinze, P. H. 1966. Biochemical and physiological changes within potato tubers during storage. Proc. Plant Science Symposium, Campbell Institute for Agr. Res. 197-208. (Pioneering Laboratory)

CUT FLOWERS AND ORNAMENTALS

Market Quality Research Division, ARS

Problem. The rapid increase in production of field-grown narcissus, gladiolus, lilies, stocks, roses, and chrysanthemums into a multimillion dollar business in Florida, California, and other states has raised many problems in marketing. Methods of packaging, as related to cooling and market life, temperature requirements during transport and for limited storage periods, atmosphere modifications for storage and transit for both cut flowers and ornamentals, and the control of Botrytis rot are among the most urgent research needs.

USDA AND COOPERATIVE PROGRAM

The Division has a limited program in market quality research on cut flowers and ornamentals, amounting to approximately 2.0 scientist man-years. This research is conducted at the Fresno and Beltsville laboratories and at the Gulf Coast Experiment Station under a cooperative agreement with the Florida Agricultural Experiment Station. The California work is supported in part by the California Floral Traffic Conference and the California Florist Association.

No projects were terminated during the year.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 6.0 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Quality maintenance in handling and packaging

1. Containers for Roses. Roses packed in vented polyethylene liners in an upright shipping container warmed to 5° to 8° F. above the ambient temperature. When deep-frozen gel ice was placed in the container above the liners, the temperature of the roses remained slightly below the ambient temperature during a 24 hour test period. The blooms were injured in the liners when temperatures were above 70° F., but with the cooling provided by gel-ice in the container, no injury occurred. Oxygen concentration decreased from 21% to less than 1% during 24 hours when roses were packed in the liner vented with 24 pin holes and was effective in maintaining the quality of the roses. Concentrations of CO₂ up to 20% caused no visible damage to the blooms or the

foliage. At temperatures below 60°, no gel-ice was necessary and the 21% O₂ was lowered to 6 to 7% without harmful effects. (MQ 2-105)

B. Quality maintenance in storage

1. Preservatives for Cut Flowers. The vase life of Dutch iris and lilacs at 70° to 75° F. was materially improved by using a chemical solution instead of water. The best preservative tested contained 3% sucrose, 400 ppm 8-hydroxyquinoline citrate and 300 ppm dimethylamino succinamic acid (Alar 90). Vase life of lilacs was increased from 2 days in water to 5 or more days in this preservative. Floret opening, floret size, and vase life of gladiolus were greatly improved by using a preservative rather than water during display at 70° F. The best preservative contained 5% sucrose, 200 ppm 8-hydroxyquinoline sulfate and 50 ppm silver acetate. Respiration rates of Friendship gladiolus at five temperatures varied from 12 to 16 mg/CO₂/kg./hr. at 33° to 84 to 142 at 70° F. (Exploratory)

2. Effect of Storage Techniques on Gladiolus Flowers. A storage period of 10 days for Florida or North Carolina gladiolus at either 33° or 40° F. after shipment was excessive as subsequent floret opening was poor. Glads stored dry 6 days in an atmosphere of 1% O₂ with 5% CO₂ at 33° or 40° F. opened slightly better after storage than control lots stored dry, in water or in air, but differences did not appear commercially important. The Friendship variety was severely injured (floret bleaching) by storage in modified atmosphere with 1% O₂ and 10% CO₂. Storage for 6 days at 33° or 40° F. in sealed 1.5-mil polyethylene bags or in a preservative solution was about as satisfactory as storage in an atmosphere of 1% O₂ with 5% CO₂. (MQ 2-105)

3. CA Storage of Lily Bulbs. Preliminary studies with three varieties of lily bulbs stored at 35°, 40°, and 45° F. for 4, 6, 8 and 10 weeks indicate some beneficial effects from reduced oxygen (3 to 10%) as compared with air. Most significant of the effects was the more rapid growth, after storage of bulbs held in the reduced-oxygen atmosphere. (MQ 2-105)

4. Ethylene Effects on Carnations. In experiments at Fresno, volatile emanations (1 ppm ethylene) from some lots of strawberries produced "sleepiness" in carnation blooms. Emanations from slightly deteriorated carnation blooms also caused sleepiness. When air from these chambers was filtered through brominated activated-charcoal before passing it over sound carnation blooms, sleepiness was prevented. Holding sound blooms in a chamber with a static atmosphere (0.2 ppm ethylene) also caused sleepiness, but when clean air was continuously passed through the holding chamber, no sleepiness occurred. Healthy carnation blooms produced about 9×10^{-6} ml of ethylene per hour, while "sleepy" blooms produced about 2×10^{-3} ml per hour per bloom. Cartons in which carnations were packed had 0.20 ppm ethylene if a few sleepy blooms were present, but only 0.075 ppm if all the blooms were sound. (MQ 2-105)

C. Postharvest disease control

1. Heat Treatments for Cut Flowers. Heating inoculated chrysanthemums for 20 minutes in moist air at 108° F. reduced Botrytis decay during 2 or 3 days at 68°. Thirty minutes at 108° or 20 minutes at 113° gave better decay control than 20 minutes at 108°, but caused injury to foliage and petals. Pom-poms (var. Hurricane and Starburst) were more resistant to heat injury than "mums", but the foliage in some cases yellowed prematurely following treatment.

Heating carnations to 108° F. for 20 or 30 minutes gave good decay control when the blooms were held at 36° F. for 4 weeks. Decay was further controlled when the blooms were held in 1/2% O₂ after the heat treatment, rather than in air. Treatments at 113° F. for 20 or 30 minutes caused injury to the foliage. (MQ 2-105)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance During Handling and Packaging

Waters, W. E. and H. F. Wilkins. 1967. Influence of intensity, duration, and date of light on growth and flowering of uncooled Easter lily. Amer. Soc. Hort. Sci. Proc. 90: 433-439. (MQ 2-105)

Quality Maintenance in Storage

Parsons, C. S., Sam Asen, and N. W. Stuart. 1967. Controlled-atmosphere storage of daffodil flowers. Amer. Soc. Hort. Sci. Proc. 90: 506-514. (MQ 2-105)

MARKETING FACILITIES, EQUIPMENT AND METHODS

Transportation and Facilities Research Division, ARS

Problem. Returns to producers and prices paid by consumers for horticultural crops are adversely affected by the use of inefficient marketing facilities, equipment and methods. Better work methods, techniques, devices, operating procedures, equipment, and facilities are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, nuts, and other horticultural crops. Such improvements at shipping points would increase the productivity of labor, prolong the storage life of the commodities, reduce bruises and injuries to these products, reduce marketing cost, expand consumption, and reflect greater returns to producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-range research program covering the development of improved work methods, techniques, devices, operating procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, nuts, and other horticultural crops. Potato research is carried on at the Red River Valley Potato Research Center, East Grand Forks, Minn.; the Potato Handling Research Center, Presque Isle, Me.; a field office at Gainesville, Fla., and the Hyattsville, Md., office; in both laboratory and commercially owned facilities; in cooperation with the North Dakota, Minnesota, Maine, and Florida Agricultural Experiment Stations, the Red River Valley Potato Growers' Association, the Market Quality Research Division, the Agricultural Engineering Research Division, the Eastern Utilization Research and Development Division, the Marketing Economics Division of ERS, and the Forest Products Laboratory of the Forest Service. Citrus fruit research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural Experiment Station, the Agricultural Engineering Research Division, the Market Quality Research Division, and commercial packers. Deciduous fruit research is carried on by the Wenatchee, Wash., and Athens, Ga., field offices and by the Hyattsville office; in both laboratory and commercially owned facilities; in cooperation with the Washington and Georgia Agricultural Experiment Stations, and the Market Quality Research Division. In Michigan, research on deciduous fruits is conducted under a research contract with Michigan State University. Vegetable research is conducted by the Gainesville, Fla., and Athens, Ga., field offices, in commercial packing plants and in laboratory facilities of the University of Florida, in cooperation with the Florida and Georgia Agricultural Experiment Stations and with the Market Quality Research Division. Sweetpotato work in North Carolina is conducted under a cooperative agreement with the North Carolina Station. Research on tree nuts is carried on by the Athens, Ga., field

office in both laboratory and commercially owned facilities in cooperation with the Georgia Agricultural Experiment Stations.

The Federal effort devoted to research in this area during the Fiscal Year 1967 totaled 11.9 scientific man-years (2.1 extramural); 4.4 to potatoes (1.1 extramural); 1.4 to citrus fruits; 4.2 to deciduous fruits and nuts (1.0 extramural); 0.9 to vegetables; and 1.0 to program leadership.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Handling, Degreening, and Packing Citrus Fruit

This research, at Gainesville, Fla., is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling, and packing citrus fruits at shipping points.

Tests on color sorting of oranges prior to degreening, based on plans made jointly by MQRD and TFRD personnel, were completed with the commercial photoelectric sorting machine at the MQRD Orlando Laboratory. Seven biweekly tests were performed. Hamlin oranges were picked and washed, then sorted by the machine into four uniform color groups, and degreened for 96 hours under controlled conditions. Observations were taken on each fruit with the Ratiospect instrument and with visual plaque readings immediately after sorting and again after one, two, three, and four days degreening. These data were taken to obtain a measurement of degreening time for each color class and are now being analyzed statistically.

During the tests, fruit was selected from each color group and measurements made on its internal quality factors. No consistent differences were found for the internal quality factors between the different color sorted groups. Data from decay tests are also being analyzed statistically. In general, after a holding period of three weeks, fruit with 0 or 1 day degreening had 10 percent decay, fruit with 2 days degreening had 22 percent decay, and fruit with 3 or 4 days degreening had 30 to 35 percent decay.

Additional tests of color sorting of citrus were made to determine the effect of unwashed fruit on the accuracy of the photoelectric color sorting machine. Hamlin, Valencia, and Temple oranges, and limes were sorted by the machine into four fairly uniform color groups. Readings also were taken on the limes and Temple oranges with the Ratiospect instrument. A test also was made to determine the effect of washing oranges prior to degreening on the subsequent degreening rate.

Color slides were made of representative color sorted groups and a movie was made of the operation of the machine while sorting oranges.

Information to be used in developing comparative cost relationships between color class degreening and the present degreening method was obtained from several citrus packinghouses.

A presentation of the color sorting research made during a meeting of the Florida Fresh Citrus Shippers' Association included a demonstration of the photoelectric sorting machine, an outline of the research, and a display of samples of the various color sorts obtained for degreening and uniformity of color. The group responded very favorably and expressed considerable interest in the research.

In accordance with the interests of the Automation Committee of the Florida Fresh Citrus Shippers' Association, studies were made by regular time study and micromotion movies to evaluate new semiautomatic equipment both for filling consumer-size bags (5- and 8-pound) and for filling cartons and crates.

Preliminary findings showed the productivity for the machine-assisted place packing as only about 5 percent better than for the established manual roll-board method of filling cartons and crates. On the filling of small bags, however, the indicated saving in labor was about 40 percent over the manual roll-board method. The possibility of relatively low equipment utilization with the application of semiautomatic machinery was clearly shown from the studies. Bag-filling machines operated during only 26 percent of the cycle at a bag-filling station. However, when fruit was bagged at a central station, rather than at individual bag-filling stations, the operating time of the bag-filling machine increased to 38 percent of the complete cycle time and the number of filling stations was reduced under given conditions from 10 to 6. With fewer stations, the investment in filling equipment would be lowered from \$3,000 to \$5,000, taking as a base 10 bag-filling stations with semiautomatic machines and master cartoning done at each filling station. Labor requirements would remain essentially the same. On the filling of 4/5-bushel cartons, preliminary data showed that one shaker-pack station (output rate 260 cartons per hour of 252-size oranges) would be equivalent to the combined output rate of six of the semiautomatic machines having one worker at each machine. Work to automatically master carton fruit packed in small bags involved construction of an experimental channel-type bagger unit having variations to make it a dual purpose unit for machine-assisted place packing of fruit in cartons and for the filling of small bags.

To explore the possibilities of ultrasonic cleaning of citrus fruit, samples of dirty oranges were sent to two equipment manufacturers for cleaning tests. Although one company indicated it was unable to obtain satisfactory cleaning action, the second company stated that its tests of the equipment worked quite well in cleaning the fruit. Arrangements have been made to bring equipment to Gainesville for performing tests.

In collaboration with the Florida Extension Service Agricultural Engineers, a layout for a new avocado-lime-mango packinghouse was developed for a Homestead, Fla., firm.

An analysis of volume-capacity relationships between pallet boxes and the standard field box was completed. Experiments involving both scale model field boxes and pallet boxes, using marbles to represent oranges, and full-size field and pallet boxes, using real fruit, were conducted to provide data for a draft of a tentative addition to or a revision of the Florida Citrus Code specifying volume of a pallet box to provide 10 field-box capacity. This report, based on the work of a committee of three representing, respectively, the Transportation and Facilities Research Division, ARS, the Agricultural Engineering Research Division, ARS, and the Lake Alfred Citrus Experiment Station, was completed and submitted to the Florida Citrus Commission for its consideration and final disposition. The tentative proposed addition to or revision of the Florida Citrus Code reads as follows: "A container of capacity equivalent to 10 standard field boxes shall have external dimension not to exceed 32 inches in overall height nor 46 inches in overall width and an internal volume to be filled with fruit of 43,500 cubic inches. Such containers for fresh fruit use should provide a headspace above the fruit of at least 2 inches to minimize fruit damage and to facilitate stacking and degreening. When a headspace is used, the level equivalent to 43,500 cubic inches shall be clearly marked inside the container on all four sides or all four corners. Any containers that differ from 43,500 cubic inches net internal volume shall be referred to the Commissioner of Agriculture for a ruling as to net contents in terms of field boxes. Such net contents shall be clearly marked on the outside of the container in letters and digits at least 2 inches high."

Work on an evaluation of handling systems for citrus fruit involving field boxes, pallet boxes, full bulk, and modified bulk was continued. Time study and other data were further processed and used in developing cycle times, including all steps between the picker and the packing line, on which to base the labor and equipment input for various combinations of equipment, quantities of fruit per load and distances between the points involved. Approximately 70 percent of the derivation of input requirement base values was completed and some of the computations for number of workers and units of equipment required at different levels of production per week were also completed.

B. Handling and Packing Deciduous Fruits

This research is directed toward the development of more efficient work methods and equipment for handling, washing, sorting, sizing and packing apples and peaches. It includes studies on the impact of electronic color sorting of apples on related packinghouse operations, an evaluation of pre-sizing and presorting apples in commercial storages and packinghouses, and the development of new equipment for prestorage sorting and sizing of apples.

1. At Wenatchee, Wash., tests were conducted with the experimental unitized brush-roll sorting and sizing line to determine if it reduced fruit damage over that in conventional grading lines, and how well it brushed and sized apples. These tests showed that fruit damage was greatly reduced and brushing

was satisfactory. However, a final decision could not be made regarding sizing accuracy. Tests with presized apples indicated that uniform density of the brushing material was more important than first thought. The original brush material on the rolls lacked the necessary uniformity for accurate sizing, and, consequently, was replaced. This change corrected the major source of sizing errors. Subsequent tests showed that some fruit was still being mis-sized, and these sizing errors were traced to the failure of some brushes to maintain a constant rate of rotation during the sizing operation. The slowing of the rotation rate was due to a lack of a positive drive which was corrected by repositioning the drive belt, straightening brush shafts that had been sprung, and replacing damaged pulleys. Tests made after these modifications with small lots of fruit indicate that the sizing problem has been solved.

If commercial tests during the 1967-68 season confirm preliminary findings, the unitized line will permit packinghouse operators the option of prestorage sorting and sizing of fruit. In addition, this equipment is expected to be as effective for peaches and pears (and perhaps other fruits and vegetables) as it is for apples; thus providing a versatility that does not exist with currently available equipment.

Preliminary sketches were prepared of an overhead accumulator for fruit from packing belts which may eliminate many of the problems associated with existing return-flow belt systems.

Work on electronic color sorting of apples was devoted exclusively to preparing a manuscript, "An Evaluation of Electronic Color Sorting." This report outlines the effects of color sorting on plant layout, other packing line operations, costs and savings associated with electronic color sorting, accuracy of sorting, and bruising of fruit. The analysis is based on annual volumes of 100,000, 200,000, and 500,000 packed boxes. This report will give packinghouse managers concrete means for evaluating a color sorting operation in their own plants, while avoiding the cost that would be involved in actually installing and using the machine.

2. At East Lansing, Mich., research was continued under a research contract with Michigan State University on designing, constructing and testing a hydrohandling system for prestorage sorting and sizing of apples. Construction of the prototype system was completed and it was installed at a commercial apple packing and storage house at Belding, Mich., for test purposes.

During the 1966 harvest, sustained runs of the prototype hydrohandling system were made with roughly 30,000 bushels of orchard-run apples received in pallet boxes of approximately 20-bushel capacity, sorted, sized, and filled back into pallet boxes. Several different varieties of fruit were used.

Based on the preliminary evaluation of the data and findings from the test runs, the contract for this research was amended to provide for the redesign of and/or additions to some of the components of the system. Working

drawings and a report describing the proposed changes had been accepted by the Department at the end of the year.

During this report period, a movie which was made primarily for record purposes was shown to at least ten industry audiences, ranging from 25 to 250 people. Also, several papers were presented to groups throughout the United States.

3. At Athens, Ga., work was continued on a project whose long-range objective is to reduce the costs of marketing fresh peaches by developing improved handling systems that incorporate the most effective utilization of labor and equipment. Emphasis was placed on grading, filling, and box makeup and supply operations. Time studies were made in five commercial peach packing-houses in Georgia and South Carolina to measure labor and equipment requirements for existing methods of performing these operations at different volume levels. Data were analyzed, compiled, and filed for future use.

A study to determine the economic feasibility of handling peaches in pallet boxes was completed. A pallet box dumper developed by an equipment manufacturer and installed in a South Carolina peach packinghouse was evaluated under commercial operating conditions. Labor and equipment requirements for the basic operations associated with pallet box handling were determined. Labor and equipment data for the field box method, which were available from previous work, were used to compute the labor and equipment costs for handling peaches by each method in a synthesized peach packinghouse operation having the capacity to dump 750 bushels per hours. Labor and equipment costs for the pallet box method were approximately \$0.03 per bushel less than for the field box method. This research also showed that peaches can be handled in pallet boxes with no more injury than in field boxes. Prior to this research no data were available to provide industry with information needed to decide whether or not to shift to pallet boxes. A manuscript, "Handling Peaches in Pallet Boxes," which is in draft form, should provide packinghouse operators the necessary decision-making data.

Additional data were obtained to compare the cost of precooling peaches in bulk hydrocoolers with that for flood-type hydrocoolers. Results of this study will aid packers in selecting hydrocooling systems that will perform efficiently and economically.

C. Handling and Packing Potatoes

1. Presque Isle, Me. Research under this project is directed toward reducing operating costs of potato storages and packinghouses by increasing the productivity of labor employed and reducing losses from bruises and mechanical injuries in handling, storing, cleaning, grading, sizing and packing potatoes. It involves the development of more efficient work methods, operating procedures, equipment, and facilities for handling, storing, and preparing for market Maine potatoes.

During the report period, research was carried on by the Maine Agricultural Experiment Station under research cooperative agreements. Intramural work was limited because the vacancy for this one-man field office was not filled until late in the report period.

Joint work was continued on the preparation of a manuscript, "Supplying the Packing Line with Potatoes in Maine Storages at Rates of 200 Hundredweight Per Hour and Above."

Under a research cooperative agreement, the Maine Agricultural Experiment Station continued work on the design and construction of an improved sizer for "long" white potatoes. Analysis of previously collected data revealed that a definite relationship exists between either height or length, and weight for all "long white" varieties. This information provided design data for the new sizer and indicated possibilities for modification of existing sizers once the magnitude of the relationships is determined.

As potatoes of a uniform size rather than weight are desired for market, the improved sizer was designed to size either by one or two dimensions. To insure that the potato's height will be used as one of the sizing criteria, the machine is designed to rotate the tubers at least twice in each size area or zone. To increase accuracy of the machine, the sizing devices are set to open a maximum of 40 millimeters at the rate of 6 millimeters per size range. In addition to the elimination of cull potatoes of less than 40 millimeters minimum dimension, provisions were made for sizing five marketable groups. Oversize potatoes comprise the seventh degree of separation.

The devices that accomplished the sizing are split spools. The machine sizes in much the same manner as an expanding-roll sizer in that a potato is supported by adjacent spools until the separating spools allow it to drop through the rolls onto a conveyor. However, an expanding-roll sizer expands in one direction only, whereas the split spools expand in two directions. Rotation assures that the potato is sized on the basis of height; lateral expansion on the basis of length.

Initial testing involved placing individual presized potatoes on the spools and observing if they were sized correctly. Adjustments were made to obtain four size categories. Next, potatoes were placed on the machine in larger groups to observe how this affected the operation.

Results of the test runs for the one-dimensional phase of the testing indicated that the most accurate sizing took place in the 40 to 55 millimeter group where 94 percent of the tubers were correctly sized. The lower percentage for correctly sized potatoes in the other size categories can be attributed to poor potato rotation due to spool slippage and to greater dimensional variations in the larger potatoes. This is substantiated by the percentage of undersized potatoes in each category which were sized on width instead of height, and were, therefore, placed in the next larger size

category. By appearance, the potatoes in each size category were sized uniformly.

During these tests, the total lateral expansion was set at a maximum of 76 millimeters. As the sample potatoes were considerably shorter than normal, the rate of lateral expansion was adjusted to maximums of 133, 138, 141, and 152 millimeters on conveyors one through four respectively. Mean lengths were reduced in size categories one, two, and four in comparison made to the one-dimensional test.

In the two-dimensional tests on the height basis, the machine sized about the same percentage correctly as in the previous tests. However, on the length basis alone, the percentage sized correctly was lower in size categories three and four; caused by potatoes that are heavier on one end tipping before falling through the spools. In a sample containing many extremely long potatoes, it is more likely that an even greater increase in the sizing accuracy would have been observed. However, the potatoes appeared uniformly sized.

Over two-thirds of the potatoes were correctly sized with a high of 100 percent being sized correctly in one category. Most of the error in sizing was caused by the width being incorrectly used as a sizing criterion. Improved potato rotation will assure that the correct dimensions are presented to the sizing spools. In every instance, each category of potatoes appeared to be uniformly sized. The results of future commercial testing should be useful in the modification of existing sizers as well as in the construction of new machines.

Under a second cooperative agreement, the Maine Agricultural Experiment Station initiated research on hydraulic handling systems for potatoes, sugar beets, and other crops.

Fluming trials were conducted in an 80-foot trapezoidal flume having an 8-inch bottom width, 15-inch top width and 14-inch depth. Three flume slopes, two rates of water flow, and two potato varieties in increments of 170 pounds per minute up to the maximum which could be handled without excessive overflow of the supply tanks were used.

Based on preliminary data, it appears that the minimum water--potato rate for Kennebecs (round whites) is about 5 to 1 and for Russet Burbanks (long whites) about 7 to 1. One inch in 15 feet appears to be the most desirable flume slope for flume lengths up to 80 feet. A slope of 1 inch in 12 feet is satisfactory if high potato rates are needed. If low potato rates are anticipated, velocities can be reduced by using a slope of 1 inch in 18 feet. At low potato rates (170 pounds per minute) velocities of from 240 to 265 feet per minute occur even on the lower slope.

To evaluate the effect of water pressure on disease development in subsequent storage, levels of 0, 5, 10, 15, 20, and 46 feet were used with both tap water and water from a flume pit. Only the 20-foot level resulted in a significant increase in lenticel infection. However, there was a proportional non-significant increase at the lower levels. No breakdown occurred in storage.

In connection with studies on sump clean out and waste disposal from flumes, soil samples were collected from potato processing plants ahead of the flumes and in the sump area following fluming where the suspended material was allowed to settle out of the effluent. Various amounts of vegetative material were found in the samples both before and after fluming.

A series of permeability measurements were made on material from the total sample as well as on the soil separates for each sample at various densities. Measurements were also made to determine the effect of a series of wetting and drying cycles on the permeability and also on the effect of adding layers of soil slurry on the top of a dried sample to simulate the effects of re-changing a disposal area. The calculations have not yet been completed for the permeability measurements.

Results of mechanical analyses on the various samples indicate that the grain-size distributions are similar for samples collected prior to and after fluming. The standard hydrometer method was used in making the mechanical analyses. A second series of mechanical analyses were made without a deflocculating agent to determine the effect of this agent on the vegetative matter. Results of this comparison are inconclusive.

A Torvane shear tester was used in determining the variation of shear strength with moisture content for the various samples. This series of tests on each sample started with a slurry (170% moisture) and continued through an air dry condition (105° F. air blowing over the sample). Two samples containing considerable vegetable matter resulted in higher shear strength at high moisture content. Preliminary indications are that this was due to the type and amount of vegetation in the sample. Considerable shrinkage and cracking during drying was noted in all samples.

A device for determining apparent viscosity of the fluming liquid was designed and constructed. It consists of 50 feet of 1-inch copper tubing coiled in a 2-foot diameter circle with instrumentation installed to measure the head loss across the total length of pipe. The associated plumbing includes a sump, the tank, pump, and valves. Preliminary tests indicate that the device should provide the desired information on the hydraulic characteristics of fluming liquids.

A 10-inch experimental pipeline system was installed on the University campus. A model system was also constructed and tested to evaluate the possibilities for solid injection by the jet pump configuration used.

2. Gainesville, Fla. Research objectives at this location are the development of more efficient work methods, operating procedures, and equipment for the handling and preparation for market of potatoes in spring-crop areas.

Work by the Gainesville office during the report year was limited to the preparation of an outline on "Possible Areas of Application of Research Effort--Potato Handling and Packing" which was discussed with a cooperative in the Hastings, Fla., area to obtain a better understanding of the needs of the potato industry and facilitate a more effective use of research resources during future years.

3. Red River Valley Potato Research Center, East Grand Forks, Minn. Work is directed toward developing more efficient work methods, techniques, devices, and equipment for the handling and preparation for market of midwestern fall-crop potatoes.

Writing of the manuscript "Handling Potatoes from Storage to the Packing Line" was completed. This report analyzes costs of handling potatoes from storage bins to the packing line in 42,000 cwt., 60,000 cwt., and 120,000 cwt. storages of multiple door, cross-alley, and deep bin types by fluming, forking to conveyors, and bulk scooping systems at handling rates of 100, 200, and 300 cwt. per hours.

The initial methods for analyses of handling seed and processing potatoes have been set up. Bulk scooping will be emphasized and the effects of storage size, scoop size and speed, storage layout, and grading line location on the performance of the handling operation will be determined.

Preliminary analyses were made of the problems associated with bulk dumping from farm trucks at the storage. Several possible solutions in the form of methods and equipment changes were considered. However, the problems are such that much additional work would be required for development of any of the systems.

A general outline was prepared for a report covering the research on the impact of cleaning and sizing fall-crop potatoes before storage on handling, storage, and packing. To substantiate earlier results, a selected sample of potatoes were manually sized with fruit rings and an array of cylinders of the same diameters as the fruit rings. Neither the cylinders or rings were found to be more accurate or to eliminate human error. A rapid manual means for accurate size checking of commercial sizers is still needed. An analysis of length, width, volume, weight, and changes during storage was made on small lots of potatoes. Linear logarithmic relationships of weight to length and width were found to correlate very well ($r = .93$ to $.99$). These results are similar to those reported earlier for Maine, but for different varieties. Actual change in weight correlated well ($r = .87$ to $.99$) with change in length. On the basis of percent change of initial weight and percent change of initial length, correlation was poor ($r = .34$ to $.68$). Actual change in weight did not correlate well with actual change in width

($r = .24$ to $.54$). Potato volume was calculated using length, width, and thickness measurements. Using the equation for the volume of an ellipsoid gave the most accurate results. Calculated volume was within -5 percent to -10 percent of the true tuber volume. The equation for the volume of a spheroid was also used. None of these gave as consistent or as accurate results as were obtained with the ellipsoid equation. Actual tuber volume was determined by weight in air and weight in water specific gravity technique. This was more accurate than determining volume by water displacement. These data were collected for three different size tubers of the Kennebec, Norgold Russett and La Rouge varieties.

D. Handling and Packing Vegetables

At Gainesville, Fla., this research has as its objective the development of improved work methods, devices, and operational procedures for the handling and preparation for market of vegetables at Florida shipping points.

Field testing of equipment to mechanically size celery stalks by weight was completed and a manuscript was drafted covering this research. The manuscript, "Size Celery Stalks by Weight with an Electronic Scale," describes tests conducted on a small package electronic checkweigher scale to determine the feasibility of separating celery stalks by weight. This scale, which will weigh stalks at a rate of approximately 200 per minute, was compared with a mechanical beam-type scale operating at a rate of 90 stalks per minute and with the subjective hand sizing method which is in universal use.

Data developed during the year indicate a scale accuracy of ± 0.065 pounds for the electronic scale and ± 0.088 pounds for the beam-type scale when the mean stalk weight was approximately 2 pounds. When workers subjectively estimate stalk size, which is commonly done when celery is packed in the field, about 33 percent of the stalks were misclassified.

Although it was found that the electronic scale was highly accurate at a stalk rate of 200 per minute, the spacing of stalks as they travel across the scale is very critical. The scale always misclassified the second stalk if there were 8 inches or less clear space between it and the preceding stalk. When stalks were located on the feed belt with 9 inches clear space between them, they could be weighed at 200 stalks per minute with a 3 percent weigh error caused by close spacing. At this rate of handling stalks, the belt on the weigh scale should operate at 426 feet per minute and the feed belt at 416 feet per minute.

Another manuscript entitled "Design for a Celery Packinghouse" was prepared. This manuscript describes a system for mechanical harvesting of celery based on design principles for a harvester established by the Florida Agricultural Experiment Station, hauling celery in bulk in pallet boxes to the packinghouse, mechanical weigh sizing of celery stalks, and manual place packing celery stalks into crates at work stations of improved design. Labor, equipment, and facility costs are established and compared with the cost to

manually harvest and pack celery in the field. The final system design will require 30 percent fewer workers than the manual field harvesting and packing system. Labor cost to mechanically harvest and pack celery in a packinghouse is 26.7 cents per crate as compared to 49.8 cents per crate for the manual harvest and field packing method.

At least one celery and sweet corn grower has constructed a packinghouse incorporating the ideas developed in the course of this research. This packinghouse reduced labor requirements from 0.24 man-hours by conventional methods to 0.14 man-hours per crate. It appears that acceptance of these methods will become general for the industry.

Three prototypes of an experimental celery packing stand were constructed and tested in a commercial packinghouse. The packing stands were of the folding type which, when activated by the worker, lowered the packed crate to a conveyor located directly in front of the stand and beneath the incoming stalk conveyor. Tests conducted during the first month of operation while the packers were unaccustomed to the equipment and methods required to pack celery in a central packinghouse (the packers had a tendency to subjectively size the celery stalks as was common in the field packing system), achieved a packing rate of approximately 77 crates per man-hour, as compared with the rate of 14 crates per man-hour for the field packing system.

Further work on color sorting of vine-ripened tomatoes with a commercial photoelectric sorting machine was done in cooperation with Market Quality Research Division. Tomatoes were sorted by this machine into four color groups and reflectance and transmittance readings were made with the Ratio-spect instrument immediately after sorting and after 1, 2, and 3 days of ripening. Also, color slides were made daily during the ripening period. The data are now being analyzed by computer. In general, the tomatoes were sorted quite well. However, it was difficult to consistently sort tomatoes showing a slight color break from those that were entirely green in color.

Feasibility studies of color sorting in commercial packinghouses indicate that the main problems to be resolved are methods of conveying the fruit through the viewing chamber and channeling the fruit into the correct color group. Also to be resolved is the desirability of separating the fruit into several color groups at a central location vs. decentralizing the color sort operation and separating color groups from the main flow of tomatoes at different locations.

With presently available commercial color sorting equipment, the object to be sorted is viewed at only two or three points and the light reflected from all points is averaged together. Work has been done on initial steps to develop new equipment which would be better adapted to sorting certain fruits and vegetables for color and also for surface defects. The object would be viewed at several equidistant points, and sorting would be based on consideration of the reflected light from each point rather than by averaging the reflectance from all viewed points. Such equipment would have the

capabilities of sorting products with a considerable variation in color on a single object or, if enough small points were viewed, it could sort products with very small surface defects. Because of the difficulties in viewing more than two or three points on an object by use of conventional optical systems, the use of fiber optics units for viewing several points has been considered. Solid state photoconductive cells have been considered for use as photoelectric sensing devices because of their inherent characteristics of ruggedness, low power requirements, and small size. Information on fiber optics equipment has been assembled and suggestions on the use of fiber optics units for this type of equipment were obtained from manufacturers. Also, information on photoconductive cells and information on spectral reflectance curves for citrus and tomatoes have been obtained.

Preliminary data on the labor requirements to grade, color sort, and pack vine-ripened tomatoes showed that the grading labor required varies directly with the quality of the incoming fruit. For average quality fruit (65 percent U.S. No. 1's and 20 to 25 percent U.S. No. 2's) and a dump rate of approximately 1800 tomatoes per hour, 20 to 25 graders will be required on the packing line. Data on wrapping and place packing tomatoes in 8-pound and 20-pound cartons showed that although the packers were generally efficient utilizing the commonly used methods, approximately 75 percent of the total time required is expended during the elements "wrap and place pack." It was also found that the fruit size within a size group varied to the extent that oftentimes one or two extra fruit had to be placed into the carton to assure that the net weight of the packed fruit was equivalent to the weight printed on the carton. The tissue in which the fruit is wrapped serves primarily as a cushion between the tomatoes as they are in transit. Packing times could be reduced by approximately 50 percent if other materials were used to provide this cushioning effect and the tomatoes were not wrapped.

E. Storage of Deciduous Fruit

1. Room Cooling Rates. The purposes of the research, at Wenatchee, Wash., are to: (1) Measure and evaluate the cooling rates of fruits stored in shipping containers of designs that should properly protect the fruit, shorten the cooling period, and maintain the fruit at proper storage temperatures; and (2) develop improved handling, stacking, and storage practices.

Cooling studies were continued with packed boxes of apples. A standard fiberboard box of tray-packed apples was used for a comparison or check. One of the test boxes had enlarged vent holes which were increased in size from the standard 1 1/2- by 1/2 inch to 1 1/2- by 1 inch and an additional hole in the center of each end 2 1/2- by 1 inch was added. In the other box tested, special holes were placed in each end. Additional tests were run on the same boxes using Dow plastic nonperforated trays. Analysis of data obtained from tests showed that the check apple box had a half cooling time of 33.2 hours. The box with enlarged holes had a half cooling time of 26.0 hours or an index of 93.5 when compared to the check with an index of 100.

The half cooling time of the box with the special holes was 14.8 hours, and an index of 45.6 when compared to the check. Therefore, the box had a half cooling time less than one-half that of the standard fiberboard boxes now being used commercially.

These tests indicate that the room cooling time of fruit packed in standard fiberboard boxes can be reduced over 50 percent by the addition of enlarged vent holes in the neutral areas of the ends of the boxes. The addition of these holes does not appear to alter the strength of the box to any great extent.

2. Refrigerated Storage. The objectives of the project at Wenatchee, Wash., are to: (1) Investigate airflow distribution methods, patterns, and rates in refrigerated fruit storages to determine and evaluate the influence of these factors on cooling fruit and bringing it to optimum storage temperatures; (2) determine and evaluate heat gain through various structural features of fruit storages and make suggestions for improved designs; (3) redesign storage houses for the most efficient handling and storage of fruit in pallet boxes; and (4) evaluate hydrocooling of apples before they are placed in storage.

Several air doors made by a refrigeration equipment company were checked for airflow pattern. These doors are of the vertical flow nonreturn type and are mounted over the doors of cold storage rooms. All doors checked had satisfactory air velocity and volume. A few small adjustments were made in the angle of the air streams to obtain the best seal on some of the doors.

A paper, "Refrigerated Storages," was prepared for presentation at the Western Regional Plan Exchange Committee Conference at the Oregon State University, Corvallis, Oregon, July 13, 1967. This paper mainly covered the design requirements for refrigerated apple storages.

3. Controlled Atmosphere Storage of Apples. Work on this project at Wenatchee, Wash., is designed to develop improved methods, techniques, equipment, and facilities for the controlled atmosphere (C.A.) storage of apples in the Pacific Northwest, and is in cooperation with the Market Quality Research Division.

Studies were continued on C.A. storages using several different systems to obtain the correct atmospheres for storage. The systems were: Caustic Soda scrubbers, using lime for CO₂ absorption, Desomatic absorber or Molecular Sieve, and Tectrol units, and also a system where Tectrol units are used to pull the rooms down to the desired atmosphere with one of the other methods used as a scrubber for the CO₂.

This was a year of considerable scald, and scald appeared on the C.A. apples as well as on those in regular storage. This indicates steps should be taken to protect the apples going into C.A. against storage scald the same as for regular storage.

The use of sacks of lime for scrubbing out the CO₂ appears to be favored over the use of caustic soda because of the ease of handling. The use of water for scrubbing out the CO₂ has been discontinued in this area because of the difficulty of obtaining the necessary lower percentage of CO₂.

F. Storage of Potatoes

Work under this program, at the Red River Valley Potato Research Center, is directed toward providing optimum storage conditions for fall-crop potatoes for table stock, seed, and processing; and developing improved layouts and designs for potato storage houses, which will permit the use of the most efficient handling and packing methods, keep injuries and mechanical damage to a minimum, and minimize construction and maintenance costs.

1. For Table Stock and Seed. Designing, drafting, and the preparation of specifications have been basically completed for a 60,000 cwt. long bin, cross alley potato storage. These will be identified as "Potato Storage--60,000 Cwt. Cross Alley," Plan No. 6018, through the Cooperative Farm Building Plan Exchange. A draft of a manuscript for a Miscellaneous Publication on this plan has been prepared and the art work for this publication is about 75 percent complete.

Designing and drafting on a fourth storage plan is about 75 percent complete. This will be identified as "Potato Storage--25,000 Cwt. Pallet Box" and also will be distributed through the Cooperative Farm Building Plan Exchange. A draft of the specifications for this storage are essentially complete. A manuscript draft was also prepared for a Miscellaneous Publication on this plan.

Full-scale testing of the 20-foot span "slotted" bin fronts was completed in a local storage. Their performance was highly satisfactory. Data gathered from this test have been incorporated as minor design changes to the plans being developed to add versatility to the installations. The "slotted" fronts designed for a storage at Stephen, Minn., have given two full years of satisfactory performance. A third commercial installation of a type of "slotted" front was inspected this year and is performing well.

Work on adaptation of "slotted" fronts to bulk scoop handling equipment was started with the installation at the Red River Valley Potato Research Center of a panel for test purposes. A splice arrangement has also been given an initial test.

The outline for a manuscript entitled "Bin Fronts for Potato Storages" was submitted and approved. Rough draft work on the manuscript is underway. This report will incorporate the results of experimental work on bin fronts and a summarization of bin front problems.

Revision and updating of the "Storage Requirement" section of a fall-crop storage bulletin was completed.

A draft of a revision of AMS-401, "Pressures on Walls of Potato Storage Bins," was prepared for review. This revision will update the report and eliminate some errors of interpretation.

2. For Processing. A third calibration of thermocouple cables and recorders was made in the chip storage bin to obtain a more reliable and accurate temperature history. The system was found to be accurate to within $\pm 1^{\circ}$ F.

All vapor pressure difference and weight loss data collected in a controlled temperature room have been plotted and regression equations calculated. No consistent patterns were observed.

A limited number of relative humidity readings were taken in a 12-foot deep chip bin that was held at 55° F. and 55 percent relative humidity with through ventilation. Depending on location in the bin, humidity increased from 1/2 to 10 percent from the bottom to the top of the potato pile. Most locations showed a 2 to 3 percent increase.

G. Cooling Deciduous Fruits

This research is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient cooling of deciduous fruit.

At Wenatchee, Wash., the project to determine the possible advantages and disadvantages of hydrocooling apples prior to storage was continued. Mature Delicious and Golden Delicious apples were hydrocooled and placed in 30° F. storage. Results show that mature apples hydrocooled to a core temperature of 40° F. and placed in 30° F. storage, and apples cooled to a storage temperature of 32° F. in 3 days and in 7 days have the same storage life expectancy and dessert quality. All samples of apples developed some storage scald. The hydrocooled fruit showed the greatest degree of storage scald.

At Athens, Ga., research carried out by the Georgia Agricultural Experiment Stations under a cooperative agreement utilizes the experimental forced-air precooler reported previously. Objectives are three-fold: (1) To evaluate performance; (2) to investigate cooling effectiveness of apples, strawberries and peaches in relation to system performance; and (3) to develop mathematical expressions of heat transfer with respect to product properties and configurations.

Performance tests demonstrated the need for additional modifications of the precooler to improve the system performance under full-load conditions. For example, the installation of turning vanes and splitters in the air ducts resulted in a 13 percent reduction in fan power requirements and improved distribution of airflow in the system. These tests, using cans of water to simulate product load, revealed a difficulty with high head pressure with the air cooled condensers. This problem was alleviated by the installation of spray nozzles for fog application to the air entering the condenser coils.

Ten pallet boxes, each containing 29 five-pound cans, were cooled from 85° to 65° F. in 30 minutes. Not considering the containers, the load imposed on the system was approximately 60,000 B.t.u./hr. These conditions resulted in a system efficiency of roughly 33 percent. Reduction of head pressure with fog application indicates that the efficiency can be increased substantially.

Eight test runs with strawberries in standard 12-pint flats were conducted to determine the effect of air temperature, air distribution, and stack depth on cooling rate. Berries in single layer flats were cooled from 63° to 31° F. at the top and 53° F. at the bottom of the containers in 30 minutes. Air temperature was 15° F. Air at 25° F. cooled the berries in the top of a single layer from 62° to 32° F. in one hour. When the flats were stacked two deep, the bottom layer cooled very slowly which indicates the need to force air through the berry interstices in the containers rather than permit it to flow over the containers as was the case in these tests. Velocity of air approaching the fruit was approximately 500 ft./min. No dessication or otherwise undesirable appearance was observed.

A draft of a manuscript, "Heat Transfer Properties and Characteristics that Affect the Design of Precooling Systems for Apples," was initiated. The manuscript will report values of thermal conductivity and thermal diffusivity, moisture content, and specific gravity of Red Delicious apples. Temperature distribution during cooling in a well-agitated water bath also will be reported. The report will include results of investigations to evaluate the temperature response of Red Delicious apples in bulk lots when cooled with air flowing through the void spaces of fruit in bulk. Results indicated that apples can be cooled by this method at a rate nearly as fast as by hydro-cooling. The practicality of this method for commercial use remains questionable from the standpoint of economy. Additional studies on an applied scale are needed to further explore this problem.

Temperature response and cooling load calculations were made to ascertain the operating requirements and the refrigeration capacities needed for hydro-cooling peaches in both bulk and flood-type hydrocoolers. Calculations of extraneous heat gain to the hydrocooler under various ambient conditions, including insulated versus non-insulated hydrocoolers, were also made. Calculations to determine the effect of condensation of water on the side-walls were supported by results of small-scale laboratory tests. The laboratory test apparatus was designed to measure the quantity of water that condenses on the sidewalls of a metal tank containing agitated ice water under various typical wet and dry bulb temperature conditions.

Calculations revealed that on a typical hot summer day (95° F. d.b. and 80° F. w.b.), approximately 10 percent of the refrigerating capacity of a hydro-cooler is used to overcome the effects of water condensing on the sidewalls of an uninsulated hydrocooler. Often as much as a 50 percent increase in hydrocooler efficiency is possible by avoiding unnecessary heat loads, extraneous sources of heat, and by maintaining full product load during operation.

H. Cooling Citrus Fruit

This research is designed to develop improved methods, operating practices and techniques for use in existing and new facilities for more efficient cooling of citrus fruit.

At Orlando, Fla., and Athens, Ga., research on thermal properties and heat transfer characteristics was continued. A manuscript for a technical bulletin entitled "Thermal Properties and Heat Transfer Characteristics of Marsh Grapefruit" was completed. A significant interaction was found between rind thickness, moisture content of the rind and juice vesicle, thermal conductivity of the rind and juice vesicles, and specific gravity. Also, as the harvest season advances from October through May, fruit was found to become more dense, its rind becomes thinner and the moisture content of the rind decreases. These findings are consistent with the observed increase in effective thermal diffusivity in relation to length of harvest season. A Marsh grapefruit, 4 inches in diameter, having an initial temperature of 85° F., is at a mass-average temperature of 50° F. after 45 minutes of cooling in a well-agitated water bath at 35° F.

At Gainesville, Fla., the report on a study of the performance of an experimental forced-air precooler at the University of Florida Campus Packinghouse with Florida citrus was further revised and edited for publication as a marketing research report. The manuscript now has the title "Experimental Forced-Air Precooling of Florida Citrus." The basic findings included in this report were previously reported.

Data obtained with the portable forced-air precooling unit on citrus fruit by the Lake Alfred Citrus Experiment Station were summarized and analyzed. Computers were used by personnel of the Gainesville, Fla., and Athens, Ga., field offices and personnel of the Fresh Fruit Handling Section, Florida Citrus Experiment Station for performing analysis of variance and Duncan's multiple range test on the precooling data (temperature reduction value). A draft of a manuscript, "Forced Air Precooling of Citrus Fruits on a Moving Conveyor," was prepared by personnel of the Florida Citrus Experiment Station.

In obtaining the data, 310 test runs were made: 186 on oranges, 68 on "Temples" and 56 with grapefruit. The trailer-mounted forced-air precooling unit ran for a total of 384 hours using 16,133 kilowatt hours of electricity. It is estimated that 115,300 individual fruit were cooled in the test operation with the machine.

This research shows: (a) Citrus fruit can be cooled with air as low as 0° F. without freeze damage, providing the fruit is not exposed too long. A sharp temperature gradient across the five cooling units from 21° down to 0° F. was more efficient than a shallower gradient from 25° down to 8° F.; (b) under optimum conditions, median size (200) oranges could be cooled 2° per minute for the first 15 minutes, thereafter the cooling curve tended to flatten; (c) in the most successful bulk runs with Valencia oranges cooling rate was 0.8° to 0.9° F. per minute and net power consumption was about 1.0 watt-hour per pound of fruit cooled 1° F.; (d) regression equations for temperature drop in

degrees Fahrenheit vs. fruit size which were developed from test runs with 200 size oranges in bulk give temperature drops of 1.40° F. and 0.74° F. when cooling times of 20 minutes and 33 minutes, respectively, were used; (e) "Temples" tended to cool faster than oranges or grapefruit. There was little difference in the cooling rate for oranges and grapefruit of identical size; (f) of the containers tested, Vexar (polyethylene mesh) bags cooled very well, open top wirebound boxes cooled well, consumer shrink-film packs cooled moderately well, ventilated poly bags were difficult to cool. Open telescope cartons became too distorted to lid properly after cooling; and (g) cooling of closed ventilated cartons or closed wirebound boxes was unsatisfactory.

Electric power cost information and design guidelines for precooling citrus in continuous flow with forced air also will be made available for industry use in a Department publication. This research indicates that there is a potential for improved quality maintenance of precooled citrus, with competitive cost, through application of air instead of water as the cooling medium.

I. Cooling Vegetables

This research at Athens, Ga., and Gainesville, Fla., is designed to develop improved methods, operating practices, and techniques for use in existing and new facilities for more efficient cooling of vegetables.

Because of a move of the Athens, Ga., field office to a new location on the University of Georgia campus and consequently, a change in laboratory facilities, it was necessary to design and construct a new laboratory test apparatus for conducting studies on heat transfer characteristics of single specimens of vegetables to air at varying temperatures and rate of flow. Although the test facility was completed, sufficient time was not available to conduct tests with sweet corn as planned.

At Gainesville, Fla., research on heat transfer characteristics of vegetables during forced-air precooling was initiated late in the report period.

Preliminary precooling tests were made at the Campus Packinghouse on small lots of snap beans and tomatoes to become more familiar with the operation of the unit and to aid in the determination of the best method of thermocouple placement for temperature measurement. A smaller chamber, 18 inches square, was built for use in the vegetable precooling tests. Further preliminary tests were made by cooling snap beans in this chamber with a load depth of 18 inches. The beans cooled from 75° F. to 35° F. in 15 minutes, with an entering air temperature of about 25° F. and an airflow rate of about 350 feet per minute. The difference in temperature between the surface and center of the beans was less than 2° F. for the entire test run.

J. Handling Vegetables in Pallet Boxes

1. Tomatoes. Recent developments in the production and harvesting of tomatoes, such as mechanical harvesting for processing, has brought about an

urgent need for the development of larger containers than field boxes for handling this commodity. Because of this need, research on handling and ripening tomatoes in pallet boxes was undertaken at East Lansing, Mich., under a cooperative agreement with the Michigan Agricultural Experiment Station.

Research on this project during the report period was confined to revising and editing the manuscript, "Handling Tomatoes in Pallet Boxes," based on the final report submitted under the above agreement. The manuscript is awaiting Department clearance for submission to the Government Printing Office.

2. Sweetpotatoes. This research is designed to increase the efficiency and reduce the unit cost of handling, curing, storing, and preparation for market of sweetpotatoes and to minimize losses from spoilage and deterioration. This work is being conducted at Raleigh, N. C., under a cooperative agreement with the North Carolina Agricultural Experiment Station and the North Carolina State Department of Agriculture.

During the report period, research on this area was confined to the completion of a manuscript, "Optimum Lowest Cost Sweetpotato Harvesting and Handling Systems," which contains the details of the research covered under the above agreement.

K. Handling and Preparing Pecans for Market

This research at Athens, Ga., is directed toward developing more efficient work methods and operating procedures, equipment, and devices for the handling and preparation for market of pecans in producing areas of the Southeastern United States.

During the report period conditioning and cracking tests were conducted with pecans for the purpose of obtaining preliminary information on the effects of variety, nut size, and conditioning on the force required to crack and the yield of perfect halves during shelling. Random samples of approximately 50 nuts were obtained for each of 8 size groups (8/16-15/16) of seedling pecans and 4 size groups (13/16-16/16) of Stuarts. Half of the nuts (25) in each sample were conditioned by soaking them in clear water for 2 hours and the other half were used as a control. All nuts were cracked with an experimental cracker and the force required to crack was recorded. The nuts were shelled by hand and the number of perfect halves counted.

It was found that the mean cracking force for the 8 size groups of seedling pecans ranged from 231-336 pounds for the untreated nuts and from 185-284 pounds for the nuts that were conditioned before cracking. The yield of perfect halves ranged from 62-84 percent for the untreated nuts and from 66-95 percent for the conditioned ones. The mean cracking force for the 4 size groups of Stuarts ranged from 205-342 pounds for the untreated nuts and from 197-261 pounds for those conditioned. The yield of perfect halves ranged from 75-96 percent and from 96-100 percent respectively, for the untreated and conditioned nuts.

These tests indicate a considerable amount of variation in the force required to crack, both among varieties and among size groups within varieties. They also indicate that conditioning reduces the force required to crack and increases the yield of perfect halves in shelling.

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CONSUMER PACKAGES AND SHIPPING CONTAINERS

Transportation and Facilities Research Division, ARS

Problem. It costs about 8 billion dollars a year to package food products, but without shipping containers and various other types of packages it would be impossible to move farm products efficiently from the widely dispersed areas of production through our complex marketing system to millions of consumers. New or improved packages and containers must be developed and evaluated to do this job more effectively. Continuing changes characterized the American marketing system. In protecting, distributing and selling perishable agricultural commodities, packages, and containers must respond to a number of marketing system changes, such as changes in (1) consumer preferences, (2) merchandising practices, (3) transportation equipment and techniques, (4) handling methods and equipment, (5) market services, (6) market organization, and (7) market outlets.

Packages and containers not only respond to changes, but changes in them stimulate improvements in other parts of the marketing system. The job of the research program in this area is to see that packages and containers keep pace with changes in the marketing system and reduce the cost of handling, transporting and storing agricultural commodities. It also seeks to improve service to consumers, promote greater sales of farm products, and increase the income of producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing program of applied research conducted by marketing specialists, industrial engineers, and agricultural economists to (1) develop new or improved consumer packages, and shipping containers for domestic and export marketing of agricultural products; (2) evaluate them from the standpoint of cost of materials and direct labor to pack, and their ability to reduce product damage and increase product salability; (3) determine at which point in the marketing system packaging can be done most effectively; (4) improve the efficiency of packaging methods to cut costs; and (5) investigate the needs for and benefits of container standardization and simplification. Current packaging and container research is on deciduous fruits, citrus fruits, vegetables, cut flowers, poultry and dairy products. The program is carried on in cooperation with experiment stations and industry in California, Oregon, Washington, Georgia, North Carolina, Virginia, Ohio, Michigan, Iowa, New York, New Jersey, Pennsylvania, Alabama, and Florida; at field stations in Orlando, Florida; Fresno, California; and Yakima, Washington; in other main producing areas; and in the principal terminal markets. This program involves 10.5 scientist man-years of which 7.5 are devoted to horticultural products.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Packages and shipping containers for horticultural products

1. Apples. A manuscript reporting on research conducted in 1965 and 1966 on evaluation of shipping containers for cell and tray-pack Golden Delicious apples is being prepared. Chipboard cell partitions, deep-pocket molded pulp trays and molded polystyrene foam trays were evaluated. The deep-pocket molded pulp and molded polystyrene foam trays performed as well but cost less than the conventionally used corrugated cell partition boxes. The chipboard cell partition boxes and conventional pulp trays did not protect the apples as well as the corrugated partition cell boxes. The results of work on the development of consumer packages for McIntosh apples were published in ARS 52-16, October 1966.
2. Apricots. Apricots jumble-packed in full telescope fiberboard boxes bruised less than those shipped in face-packed wood boxes. This finding was based on transcontinental test shipments made during the 1966 apricot season. The cost of containers, equipment, labor and transport to pack and ship apricots in jumble-filled fiberboard and place-packed wood boxes will be determined during the 1967 apricot season.
3. Italian Prunes. Italian prunes shipped in jumble-packed wirebound fiberboard - wood veneer boxes bruised less than those shipped in face-packed wood veneer baskets. Transcontinental test shipments of Italian prunes packed in these two containers were made during the 1966 season. The cost of containers, equipment, labor and transport to pack and ship Italian prunes in jumble-pack and face-pack containers will be determined during the 1967 season.
4. Grapes. California grapes packed in expanded polystyrene foam shipping containers arrived in Eastern markets with slightly fewer bruised and shattered berries than grapes packed in standard wood display lugs. These results were obtained from test shipments made during the 1966 grape season. Additional test shipments are being made during the 1967 grape season. The costs of packing, handling and transport for grapes packed and shipped in the polystyrene foam and standard wood boxes will be obtained during the 1967 season. Receivers generally liked the polystyrene foam boxes for grapes, although breakage of the boxes was a problem in test shipments made during the 1966 season. The boxes were redesigned for the 1967 tests.
5. Temple Oranges. Temple oranges packed and shipped in polyvinyl chloride (PVC) cell trays arrived in terminal markets with less bruising than comparable oranges place-packed in wirebound wood crates or fiberboard boxes. Sixteen truck test shipments of Temple oranges packed in PVC shipping trays in fiberboard boxes and place-packed in fiberboard boxes and wirebound crates were made from Florida to five Eastern terminal

markets. The cost of packing Temple oranges in the PVC cell trays was \$.59 per 4/5 bushel box equivalent, \$.42 for wirebound crates and \$.31 for fiberboard boxes. A manuscript is being prepared for publication.

6. Grapefruit and Murcott Oranges. Results of exploratory studies on packaging grapefruit halves and peeled whole Murcott oranges at shipping point were promising. Further studies are planned during the 1967-1968 citrus season to test the feasibility of marketing packaged grapefruit halves and peeled oranges in vending machines, restaurants, and retail food stores.

7. Plums, Nectarines, and Bartlett Pears. Investigations to determine the costs and feasibility of marketing Western plums, nectarines, and Bartlett pears packed in three sizes of shipping containers and prepackaging them in terminal prepackaging plants and in retail stores are being made under contract by Food Industries Research and Engineering. The fruit is being packed in place-packed boxes, jumble-packed boxes and in large bulk-bin boxes. One pilot test shipment from California to Boston, Massachusetts, was completed in 1966. Four test shipments of each of the three kinds of fruit will be made in 1967.

8. Pears. The results of the work done on the development of prepackaging pears at shipping point were published in Marketing Research Report No. 758, November 1966.

9. Tomatoes. Results of the work done on the cost and use of ozone in tomato ripening rooms were published in ARS 52-17, October 1966.

10. Tomato Transplants. In cooperation with Crops Research Division, ARS, the feasibility of developing improved containers for shipping tomato transplants from Georgia to northern tomato producing areas was investigated. Tomato transplants are usually harvested and then graded and packed in bunches wrapped with Kraft paper in packing sheds. The paper wrapped bunches of tomato plants are then packed in wirebound crates. The feasibility of packing the tomato transplants directly into shipping containers from a mechanical harvesting machine developed by Crops Research Division will be tested next season. New shipping containers such as wax-coated fiberboard boxes and accessory packaging materials such as polyethylene film and polyethylene film laminated to crepe paper will be tested.

11. Standardization of containers for fresh fruits and vegetables. A pilot study on the extent of use, dimensions, net weights and specifications of shipping containers used for fresh fruits and vegetables in the United States was completed under contract by the Research Triangle Institute, Raleigh, North Carolina. The pilot survey was undertaken in four warehouses, in each of the cities of Los Angeles and New York over four seasons of the year. The purpose of the study was to provide information to develop

a national survey. In the pilot study 112 different size boxes were found in use for apples, 45 for grapes, and 22 for cauliflower. These examples of proliferation in sizes of containers indicate the lack of uniformity in use of containers for fresh produce.

12. Flowers.

Chrysanthemums. Twenty cents a box can be saved by packing and shipping California chrysanthemums in a regular slotted (RSC) box instead of in the conventionally used part-telescope fiberboard box. Packing labor and accessory packing materials for the RSC box were more expensive, about \$.20, but the smaller cubic space occupied by the box saved \$.40 in air freight cost. Another experimental container tested for California chrysanthemums, a foamboard (polystyrene foam sandwiched between two facings of kraft paper) costs \$.61 more than the part-telescope fiberboard box. It was presumed that the foamboard box would provide better insulation for the cut chrysanthemums than the fiberboard boxes, but all three boxes protected the cut flowers from changes in ambient temperature equally well.

Carnations. Twelve test shipments of Colorado carnations packed in fiberboard shipping containers of various designs and with various types of liners and accessory packaging materials were made during the 1966-1967 season. Stem breakage averaged about 3 percent in all of these test shipments. Container damage was not a serious problem. Minor modifications in packing these flowers offer potential savings. A wood cleat instead of metal tipped cleat is less expensive and offers potential economies. Polyethylene film laminated to crepe paper and an expanded polystyrene foam liner provided better insulation at less cost than currently used materials such as spun fiberglass blankets and air cell liner materials.

B. Packages and shipping containers for overseas markets

1. Fruits and Vegetables.

Four test shipments of apples were made from Portland, Oregon, to Stockholm, Sweden. The apples, Golden Delicious, Red Delicious and Newtons were shipped in tray-pack boxes and cell-boxes, each holding about 42 pounds, and in 4 cell pallet boxes holding about 800 pounds. Some tray-pack and cell-pack boxes of apples were handled individually, and some were handled unitized on pallets. Data developed in these tests indicate that palletization of boxes offer savings of \$1.00 per 100 pounds. Packing, handling, and transporting the apples in the 800-pound 4-cell pallet box instead of in 42-pound boxes handled individually offers savings of \$2.58 per 100 pounds. In these shipments to Stockholm there were no significant differences in the amount of bruising of apples packed in the different containers and handled individually or unitized.

Rutgers University completed a contract studying the feasibility of packing and shipping cell-pack Golden Delicious and McIntosh apples in a 30 by 50 cm. box--one of the proposed European standard containers. McIntosh apples and Golden Delicious apples packed in cell boxes with 30 by 50 cm. outside dimensions did not show any more bruising than comparable apples packed in conventionally used cell-pack boxes in test shipments made from apple producing areas to New York City. The tests indicate that the packing of all the sizes of apples of these two varieties that are exported in one dimensional size cell-box would increase the costs of placing apples in Europe about 1/2 cent per pound.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Shipping Containers and Packages for Fresh Fruits and Vegetables

Nicholas, C.J., and Risse, Lawrence A. January 1967. Containerized Turkey Shipping Cuts Its Teeth. Poultry Meat.

Fountain, James B., and Chapogas, Peter G. November 1966. Prepackaging Pears at Shipping Point. MRR-758.

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Hinsch, Robert Tom. October 1966. New Overwrapped Trays for McIntosh Apples. ARS No. 52-16.

Mallison, Earl D., and Spalding, Donald H. October 1966. Use of Ozone in Tomato Ripening Rooms. ARS No. 52-17.

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TRANSPORT EQUIPMENT AND TECHNIQUES

Transportation and Facilities Research Division, ARS

Problem. The cost of transporting farm products to market in 1966 was about 5 billion dollars. Cost of transporting supplies used in farm production was more than one billion dollars. Further, costs of other marketing and production functions, such as loading and unloading vehicles, packaging, storage and processing, also are affected by the efficiency of transport. These costs are important to the American farmer because they influence the return he receives from the sale of his products. They also are important to the American consumer because they influence the price he pays for his food. Therefore, the prosperity and efficiency of our entire agricultural industry and the economic well-being of the American consumer are closely tied to the efficiency of our transport system.

In spite of the importance of transport to agriculture and the consuming public, research to make it more efficient and less costly has been meager. New advances in transport and engineering technology, including the development of new materials, new building and operating techniques for transport equipment, containerization and unitization--all offer opportunities to improve agricultural transport. Translating these and other opportunities into working advantages for our agricultural producers and consumers requires a strong program of economic-engineering research. Such a program will help increase returns to American farmers, provide better products at lower costs to American consumers, and improve the competitive position of our farm products in foreign markets.

USDA AND COOPERATIVE PROGRAM

The economic-engineering research in this field is a long-range program. It seeks to develop improved transport facilities, equipment and techniques and more efficient ways of using them in transporting agricultural products and supplies. It is interdisciplinary in nature, drawing upon the training and experience of economists, mechanical and industrial engineers, marketing specialists and various other scientists. All the work is done with the cooperation of transport firms, transport and refrigeration equipment manufacturers and lessors, trade associations, State universities and experiment stations. Field studies are carried out throughout the U. S. and on overseas shipments. Only one field station, Orlando, Florida, presently is maintained to support this research program. Part of the work is accomplished through research contracts and cooperative agreements.

At the present time, work is underway in each of the following fields:

(1) Transport equipment, (2) refrigeration equipment and techniques, (3) better utilization of transport equipment and techniques, (4) loading methods, including unitized and palletized loading, and (5) overseas transport.

This program of research involves 12.0 scientist man-years of which 3.8 is devoted to fruits and vegetables, 0.8 to floral products, and 2.8 to overseas transport of fruits and vegetables.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

Flower Transport. Research was continued on transport and handling of carnations. The objective of this work is to seek ways of lowering the cost of transport and physical distribution and to deliver a better product to the consumer. Improvements appear possible in two areas. One is maintenance of flower temperature in transit and the other is distributing the carnations in the bud stage instead of as open flowers.

Ten air transport tests of carnations were made from Denver, Colorado, to Eastern destinations during the year. Flowers averaged about 54° during distribution, or 20 degrees above the desired temperature of 34°. Aircraft cargo compartments were held in the range of 50° to 65° and air transport accounted for about 20 percent of the total time the flowers were in transit. During the other 80 percent of transit time accounted for by ground transport and handling there was no control of ambient temperature. From the tests it appears that, for the foreseeable future, temperature of flowers moving by air will have to be maintained by means of a coolant inside a properly insulated carton, rather than by equipment and facilities in which the flowers are held or transported. A promising possibility of reducing the cost of transporting and handling carnations is shipping the flowers in the bud instead of open flower stage, with flowers to be brought to the bloom stage by the destination wholesaler or retailer. In the last three of the air transport tests, carnations were shipped by both methods. These preliminary tests indicate a possible saving of over one million dollars per year with a bud distribution system. Further tests and analysis of possible economies will be made in the coming year.

Transport Techniques

1. Overseas Transport. Three container van loads of fruits and vegetables from Texas and Florida shipped to West Berlin for exhibit and sale at the Green Week Food Fair were studied during the year. Included in the shipping experiments were one van load of pink grapefruit and one van load of one-pound film bags of carrots from the Rio Grande Valley in Texas and one van load of mixed vegetables from Florida, consisting of celery, radishes, Chinese cabbage, romaine, endive, and Boston lettuce. All three test shipments arrived with no losses from pilferage or physical damage. Because of sufficient pretransit cooling of the vegetables, periodic exchange of air in the van load of grapefruit to prevent the accumulation of harmful concentrations of carbon dioxide, and adequate refrigeration in transit, all products were delivered in good condition. Transport and handling costs were obtained for all three shipments from packing plants as far as Rotterdam. However, cost data for land transport to West Berlin are not yet complete.

Researchers assisted shippers in loading the vans and in making arrangements for protection of the products during transport and handling. The research was conducted in cooperation with the Market Quality Research Division, ARS, the Texas Farm Bureau and the Florida Fresh Fruit and Vegetable Association. More tests are planned during the coming year to gather data on condition of shipments and transport and handling costs. Following the first experimental shipment of Texas pink grapefruit, an additional 35 van loads were shipped to Europe on a regular commercial basis.

Shipping experiments also were made with containerized shipments of Florida sweet corn to West Germany in mechanically refrigerated trailers. Transport researchers provided supervision during loading to insure proper stacking, sorting and icing of the loads. Air and product temperatures were taken during the domestic portion of the trip. Data on icing and re-icing to provide adequate cooling and moisture for the product were obtained. While the corn arrived in good condition, the test results were inconclusive. In the two trailer loads, the crushed ice placed on top of the load was melted completely before the trailers arrived at Norfolk, Virginia, for loading aboard ship. Observation of the operation of the trailers' refrigeration systems showed that the rapid rate of ice meltage was caused by the mechanical refrigeration units being periodically switched on to the heating cycle by their thermostatic controls. Work is being continued to solve this problem by modifying the thermostatic controls of the refrigeration units. The research is being done in cooperation with the Fruit Growers Express Company, owners of the trailers, refrigeration equipment manufacturers, the railroad and shippers.

In cooperation with the Florida Citrus Exchange, four container shipments of grapefruit to Paris were studied. The vans were transported by piggyback to New York where they were transferred to a high-speed containership bound for LeHavre. Transport researchers assisted shippers in loading the vans and in making arrangements for protection of the products during transport and handling. Although about one-fourth of the boxes were poorly closed, the shipment arrived in Paris with no losses from damage and pilferage. Savings on ocean freight costs because of a 10 percent discount in ocean freight rates for container shipments were 11.5 cents a box, or \$146.80 per van. Savings in cargo insurance also amounted to \$4.70 per van load. Work on an interim report on transporting fruits and vegetables to overseas markets was begun during the year.

2. Improved Loading of Bagged Onions. The purpose of this research was to find ways to improve load stability and increase air circulation in shipments of bagged onions during transport. Different load patterns for the bags and new cushioning materials which might help to reduce container and product damage were evaluated. New stacking patterns for both rail and truck shipments to provide better air circulation through the loads have been developed. The new patterns provided numerous vertical air channels which

extend from top to bottom of the loads in rail cars and from the front to rear of trailer loads. Better circulation of incoming air through the load helps remove excess heat and moisture, and the development of decay. This was accomplished with no reduction in the number of bags in each shipment by increasing the height of the load.

The field work and much of the manuscript reporting the results were completed at the beginning of the year. During the year the data were further tested for statistical significance and extensive revisions were made on the manuscript. The report will be published and the project terminated during the coming year.

3. Pallet Containers For Transport of Apples. This research sought ways to reduce container, packing and transport costs by shipping and handling apples in pallet containers to terminal market prepackaging plants. Savings from use of pallet containers for this purpose instead of the conventional 40-pound corrugated fiberboard boxes were found to range from 0.1 cent a pound, or about \$150 a carload for one trip to 0.2 cents a pound, or about \$300 a carload when the pallet containers were used for two trips. The savings result from lower container, packing, handling, freight and refrigeration costs when pallet containers are used. The report on this research was extensively rewritten during the year. It will be completed and the project terminated in the coming year.

4. Heavier Loading of Watermelons. Results of this research showed that savings in railroad out-of-pocket costs of transporting watermelons from southeastern producing areas to northern markets would have been more than \$170,000 a year if the melons had been loaded 7 layers high instead of the conventional 5 layers high. The research also showed that about \$7,000 in cost of material used to cushion the melons in rail shipments could be gained from heavier loading. Although there were more damaged melons in the heavier loaded cars than in the lighter loads, the increase in the amount of damage was not related to the increase in load height. Studies comparing the effectiveness of expanded polystyrene foam and straw for cushioning the melons in rail cars showed no significant difference in the amount of melon damage, but the foam had some advantages such as cleanliness, ease of application and helping make possible better ventilation in the loads during transit. The results of this research are reported in ARS 52-22, "Heavier Loading of Watermelons in Rail Cars and Piggyback Trailers."

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Transport Equipment

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Ashby, B. H. May 1967. USDA Has Some Answers, Will Develop Others For Perishables. Air Cargo.

Transport Techniques

Clayton, J. E., Breakiron, P. L. and Goddard, W. F., Jr. August 1966. The Omniferent Container, Handling and Shipping.

Breakiron, P. L., Nicholas, C. J. Stewart, J. K., and Kurtenacker, R. S. January 1967. Reducing Transport Damage in Top-Iced Shipments of Fresh Vegetables in Bushel Baskets. (A Study of Rail Shipments of Fresh Peas). MRR-772.

Clayton, J. E. April 1967. What's Ahead in Containerization. Paper presented at the Agricultural Policy Institute Conference: Transportation and the Changing South. Raleigh, N. C.

Clayton, J. E. May 1967. Need Van to Haul Fresh Food Overseas. Container News.

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Clayton, J. E. June 1967. Van Movements Reduce Spoilage. Container News.

Clayton, J. E. January 1967. Containerization Research by the U. S. Department of Agriculture. Paper presented at the Seventh Annual Conference. Containerization and Packaging. New York, New York.

COOPERATIVE MARKETING

Farmer Cooperative Service

Problem: Farmers continue to increase their use of marketing cooperatives.

Marketing cooperatives face major changes in handling, processing, transportation, and distribution technology as well as in market organization and practices. Farmers also have changed and cooperatives need research findings to help members strengthen their bargaining power, increase marketing efficiency, and effectively meet the quality, quantity, and service needs of today's markets.

Farmers own and operate marketing cooperatives specifically to increase their income from the sale of crops and livestock. Gains are not automatic, however.

Cooperatives must plan and actually conduct the specific marketing programs and services that will yield best returns to their members. Marketing cooperatives must know what the consumer wants. They must be able to estimate the cost of serving the market in different ways. They must understand the possibility of major economies in a well-managed joint sales program, methods and potentials of bargaining, and impact of a changing market structure on operations.

Management must achieve minimum costs through appropriate organization, good use of existing plant and personnel, and correct selection and use of new equipment and methods.

USDA and Cooperative Program

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies cover organization, operation, and role of cooperatives in marketing. While the research helps improve cooperatives operations, the results often benefit other marketing firms.

The work is centered in Washington, D.C. The Service, however, has many studies done under contract or in cooperation with various State experiment stations, extension services, land-grant colleges, universities, cooperatives and private research organizations.

Federal scientific man-years devoted to research in this area totaled 11.6. Of this number, 1.7 was devoted to improving sales, distribution, and pricing practices; 3.5 to potentials in cooperative marketing; 2.6 to improving operating and handling methods; and 3.8 to improving the organizations, financing, and management of marketing cooperatives. All research was in the field of economics.

Program of State Experiment Stations

The research effort of the State experiment stations in this area totaled 2.8 scientist man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Improving cooperative sales, distribution, and pricing practices

Bargaining. Research continues on bargaining methods in fruits and vegetables. This research appraises the status, role, and potentials of cooperative bargaining as a means of stabilizing and enhancing incomes of producers.

B. Potentials in cooperative marketing

Fruits and Vegetables. Work continues on a study of the status and trends in the cooperative marketing of fruits and vegetables. Ways these cooperatives might increase their operating efficiency and marketing effectiveness through integration, coordination, consolidation, expansion, and other means are also being evaluated.

A study to determine the potential of small fruit and vegetable cooperatives on the Coastal Plains of North Carolina continues. This work is being done under a cooperative agreement by the Agricultural and Technical College of North Carolina.

Potatoes. A study of the role of cooperatives in the market structure of the major potato producing areas of the United States continues.

Vegetables. Work was initiated on a study to determine the potential of marketing vegetables cooperatively in Tennessee. This work is being conducted in cooperation with the University of Tennessee.

C. Improving the organization, financing, and management of marketing cooperatives

Citrus. A study to appraise the possibilities of a group of Florida processing cooperatives coordinating their marketing efforts was completed. Findings indicate that a central sales organization would materially improve the marketing ability of these cooperatives.

Fruits and Vegetables. A study is continuing on organizational characteristics and operating methods of selected marketing agencies that have successfully marketed fruits and vegetables for member associations on a joint basis.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Improving Cooperative Sales, Distribution, and Pricing Practices

1967. Proceedings of the 11th National Bargaining Conference. FCS Unnumbered Report.

Potentials in Cooperative Marketing

Markeson, C. B. 1967. Focusing on Market Needs for Fruits and Vegetables.
News for Farmer Cooperatives (Jan.).

MARKETING ECONOMICS RESEARCH

Marketing Economics Division, ERS

Problem: Economic research in agricultural marketing provides a framework for developing and maintaining an effective and efficient system of marketing farm products and assuring equitable returns to farmers and marketing agencies. The marketing of farm products continues to become more complex and dynamic because of advances in technology, changes in composition and location of the population, and demands for meeting food and fiber needs in a large part of the world. Not only are structural changes taking place within the marketing segment of the economy but large segments of the processing industry are relocating to meet shifts occurring in labor resources, transportation rates and services, and consumer markets. Producers and distributors must be armed with the most up-to-date and accurate information available to cope with and adjust to changes occurring within and outside the agricultural economy.

Within the framework of the competitive system the food and fiber industries must perform in an efficient manner to maintain viable industries and help sustain a high standard of living. Marketing economics research provides a service in collecting, analyzing and publishing objective information. The information furnished through research is a form of market intelligence which the private enterprise system utilizes in making sound decisions in the marketing of farm products. Likewise, research findings provide a basis for developing guidelines in public policy as well as concepts for needed new legislation.

Marketing research helps facilitate the communication of consumer wants and desires back through the marketing system to the producer. As never before, information is needed to guide and direct the production and development of new products to meet the demands of a rapidly changing population. Producers, processors, and distributors must constantly seek an understanding of the economics of product quality, variety, and substitution to be responsive to consumer demands and utilize resources efficiently.

Market intelligence through research in the Division is furnished in areas such as: measurement and evaluation of changes in the structure of the market and the impact of changes on producers, processors and distributors; performance of the market in terms of efficiency and equity are continually being assessed; farm-retail spreads are maintained on a continuing basis for the major commodities and reported specifically to a congressional committee as well as to the general public; studies in interregional competition, pricing, and transportation form a part of the research program; evaluation of public programs as they relate to the farm economy and public welfare are analyzed; means of improving farmers' bargaining power in the market place are continually under study; and work in utilization economics as it pertains to new products and processes

form a part of the research effort. Information furnished through research in these and other areas establish a basis for adjusting to change, keeping abreast of technological and scientific developments, building a marketing system responsive to demands of consumers and formulating sound policy decisions, both public and private, as they relate to marketing food and fiber.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program of economic research designed to provide timely and accurate market intelligence to producers, processors and distributors. The program of work involves both basic and applied aspects of marketing economics research. The program covers commodity and functional problems that are regional or national in scope. In addition to the long-term, on-going research work of the Division, frequently short-term, service-type assignments are carried out for the Secretary of Agriculture or other agencies within the Department having specific problems for which the staff of the Division is uniquely equipped to analyze and make recommendations.

Research studies are often conducted in cooperation with other USDA agencies, other Federal departments, and State Agricultural Experiment Stations. On occasion, cooperative work is undertaken with processors and distributors of agricultural products, transportation agencies, and agriculturally oriented groups. Financial contributions to the Division's research efforts are sometimes made by industry groups which provide a strengthening of the research effort.

The research program and related program activities are conducted from headquarters in Washington, D. C. A limited number of field stations are located throughout the United States, a major part of them being at land-grant institutions. Field station personnel perform a special service by keeping the Division alerted and informed on emerging problems in marketing as well as conducting joint research projects with station personnel. Also, economists are located at each of the four USDA Utilization Research and Development Laboratories. The scientific effort devoted to marketing research during the reporting year amounted to approximately 118 professional man-years.

PROGRAM OF STATE EXPERIMENT STATIONS

A. Efficiency of Resource Allocation in Marketing

A total of 141.8 scientist man-years is devoted to this area of research.

B. Competitive Situation of Input and Output Marketing Firms

A total of 17.0 scientist man-years is devoted to this area of research.

C. Bargaining and Income Position of Farmers in Marketing

A total of 2.3 scientist man-years is devoted to this area of research.

D. Role of Consumers in Marketing

A total of 17.0 scientist man-years is devoted to this area of research.

E. Location and Growth Economics

A total of 24.7 scientist man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Efficiency of Resource Allocation in Marketing

Research on the efficiency of performing the marketing functions evaluates the impacts of reduced costs and subsequent adjustments on farmers, marketing agencies and consumers. It relates to the adoption of new technology and innovations by marketing firms and its affect on costs of distributing farm products. In some cases, evaluation of alternative methods of performing the marketing functions is made possible through generating input-output coefficients which demonstrate least-cost methods of performing an individual function. Relationships are shown between costs and alternative methods (innovation and technology) or between costs and volume (economies of scale). Research which describes the flow of products through the various marketing channels is designed to provide sufficient background knowledge to evaluate efficiencies in performing the various marketing functions.

Fruits and Vegetables

Results of capacity analyses in the Southern Region show that vegetable canners and freezers utilized 57 and 73 percent of their processing capacity respectively when capacity was calculated under usual operating conditions for each plant. This leaves a surplus capacity for vegetables of 25 million 24/303 case equivalents in canning plants and 73 million pounds in freezing plants.

Input-output coefficients and input costs have been compiled for freezing and canning 11 vegetables that are important to processors in the South.

Work on input-output coefficients and input costs for grading, packing, and storage of the major fresh vegetables produced in the South is to be completed. Planning curves for the various vegetable processing lines are to be developed from the input-output and cost data.

B. Competitive Situation of Input and Output Marketing Firms

Research in this area is concerned with the organizational characteristics and practices of marketing firms which effect competition among firms and their relative bargaining position as both buyers and sellers. Studies relate to the measurement and evaluation of concentration, mergers and the various dimensions of integration and diversification of firms. These factors assist in evaluating the marketing position or power of the intermediary marketing agencies. Information on profit ratios and descriptive statistics relating to the farm-retail price spreads and the Marketing Bill serve as bench mark indicators of market position and power.

Fruits and Vegetables

Of particular significance among the fruit crops in the 1966-67 season was the record large production of Florida oranges. As a result, the average retail price for fresh Florida oranges in 4 markets of record was \$9.00 per 90 pound box compared with \$10.21 the previous season. Despite this price decrease, the wholesale-retail price spread increased 10 cents to \$4.59. In contrast, the shipping point-wholesale price spread decreased from \$2.15 in 1965-66 to \$1.44 in 1966-67. The amount received by the grower and packer was \$2.97 per box in 1966-67 compared with \$3.57 a year earlier.

Potato prices in 1966-67 moved upward from a year earlier although they did not reach the high levels of 1964-65. Western russets averaged \$10.76 per 100 pounds at retail in 4 markets, which was nearly \$1.00 above the previous season. Of this increase, 41 cents went to the wholesale-retail spread, 17 cents to the shipping point-wholesale spread and the remaining 41 cents to grower and packer returns.

Round white potatoes, primarily from Maine, averaged \$7.49 per 100 pounds at retail in 3 markets of record compared with \$6.88 a season earlier. Most of the increase--62 cents--went to the wholesale-retail spread bringing it to \$4.34. The shipping point-wholesale spread decreased from 76 cents to 68 cents. Grower and packer returns increased from \$2.40 in 1965-66 to \$2.47 in 1966-67.

The opening of a new wholesale produce market as part of a Food Distribution Center in 1959 resulted in greater centralization of produce wholesaling in Philadelphia. About half of the produce wholesalers in Philadelphia, handling

two-thirds of the total volume (including resales) were located in the Center in 1964. These firms accounted for three-fourths of the produce entering the city that year. In 1958, before the new market was opened, about 60 percent of all wholesalers were located in the Dock Street area. These firms accounted for about one-half the total volume in 1958, but only one-third of the produce arriving in the city.

In 1964, there were 154 wholesalers in the Philadelphia market--58 fewer than in 1958. Most of the decline was among small firms handling less than 3,000 tons per year.

Although the volume of fresh produce entering the Philadelphia market increased 7 percent between 1958 and 1964, wholesalers' share of the market declined. Direct receipts by chainstores increased from 33 percent of all market receipts in 1958 to 42 percent in 1964. Chainstores were buying a greatly reduced proportion of their produce needs locally--33 percent in 1958 and 18 percent in 1964.

Ornamentals

Nearly 67,000 acres were used for the production of woody ornamentals in 11 Southern States in 1965. Sales from this production were estimated to be nearly \$44 million. The woody ornamental nursery industry is typified by a large number of small units. In the 11 states surveyed, only 17 percent of the nurseries accounted for more than 70 percent of the total sales. Broad leaf evergreens were the most popular item produced. Eighty-four percent of the nurseries produced broad leafs, compared with 69 percent producing narrow leaf, 61 percent producing deciduous shrubs, 63 percent ornamental trees, and only 20 percent producing vines.

C. Bargaining and Income Position of Farmers in Marketing

It has long been assumed that, because of the purely competitive structure of the production process in agriculture, farmers are at a disadvantage in the marketing process. Consequently, considerable public enabling legislature has been enacted to strengthen the bargaining and income position of farmers. Examples are the establishment of publicly financed market news, crop reporting and estimating, and legislation to enable farmers to band together in their buying and selling activities. Farmers also engage in self-sponsored programs such as advertising to differentiate their products in the market place. Continuing research is designed to evaluate the effectiveness of these programs and to seek alternative ways in which farmers can organize to strengthen their market and income position.

D. Role of Consumers in Marketing

Research in marketing economics concerns itself with the interests of the consumer as well as those of the farmer and marketing agencies. Research in this area is designed to facilitate the communication of consumers' wants and desires back through the marketing system to the production process. Research is designed to evaluate the nature of demands so that resources can be more efficiently allocated in the production process.

Fruits and Vegetables

Research conducted in cooperation with the Florida Citrus Commission and the Market Research Corporation of America indicates that purchases of juices and fruit drinks by household consumers in January-March 1967 were up 5 percent--3.5 million cases single strength equivalent--in comparison with the same quarter of 1966. Orange juices accounted for about 44 percent of the fruit beverages bought for home use during the quarter, up from 40 percent a year earlier.

Flowers

A current study to determine the attributes of consumers (and nonconsumers) of flowers, plants, seeds, and ornamentals indicates that approximately 60 percent of the purchases of flowers and potted plants are made in florist shops. Independent garden centers, and garden centers affiliated with department stores each make 12 percent of the number of sales. Six percent of the purchases are made in supermarkets.

Most purchases of flowers (21 percent) are made for the home. Funerals comprise 18 percent and gardens 17 percent of flower purchases. Most of the purchases are made by women.

E. Location and Growth Economics

Fruits and Vegetables

Research in the Red River Valley (Minnesota-North Dakota) potato market indicates that production in that area has increased steadily from an annual average of 14.1 million cwt. in 1950-54 to 21.6 million cwt. in 1965-66. The Valley now accounts for 85 percent of the Minnesota-North Dakota production and 7.3 percent of the U.S. total. The processing market has expanded more rapidly than the tablestock market. The volume of potatoes sold for chipping has nearly tripled since the mid-1950's.

A study has been undertaken to determine production patterns within and among winter vegetable producing areas and distribution patterns of their produce among market centers of the U.S. consistent with optimization of consumer requirements, producer returns, and factor utilization as governed by specified qualitative and quantitative supply and demand constraints. Initial phases of the study have emphasized conceptualizing and formulating a mathematical simulation of the winter vegetable industry.

Research to determine the competitive position of the North Central region in marketing fruits and vegetables has been undertaken in cooperation with the University of Wisconsin and other North Central states. Under contract, Agri Research, Inc., is beginning a study to determine the existing canning and freezing capacity in the region. Later phases of the study will include demand analyses, and studies to determine the feasibility of establishing additional processing facilities. This project is just getting underway; preliminary results are not available.

Peanuts

Work has been started on the development of an interregional analysis of the peanut industry. The State Experiment Stations in Georgia and Texas, under contract with ERS, are well along on collecting and analyzing data concerning peanut grower harvesting and marketing practices and the costs associated with these activities in their respective areas. This information, along with a considerable amount of other data from various sources will provide the basic input data for an interregional model of the industry.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Efficiency of Resource Allocation in Marketing

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Lundquist, Dorothy M. and Powell, Jules V., September 1966. A Bibliography on Marketing Woody Plants and Related Nursery Products 1944-65. Misc. Publ. No. 1039, 23 pp.

Lundquist, Dorothy M. and Powell, Jules V., July 1967. Bibliography of Tree Nut Production and Marketing Research, 1960-65. Misc. Publ. No. 1064, 39 pp.

Van Dress, Michael G. and Freund, William H., May 1967. Survey of the Market for Food Away From Home: A Preliminary Overview of Basic Tabulations From Phase I of the Survey. Unnumbered.

Role of Consumers in Marketing

Havas, Nick., July 1967. Highlights...A Survey of the Retail Florist Industry. ERS-298, 2 pp.

Johnson, Clive E., July-September 1966; October-December 1966; and January-March 1967. Consumer Purchases of Citrus Fruit Juices, Drinks, and Other Products. CPFJ-166, 167, 168.

Mitchell, Vernice C., April-June 1966. Consumer Purchases of Citrus Fruit Juices, Drinks, and Other Products. CPFJ-165, 26 pp.

Location and Growth Economics

Chai, J. C., Hanes, J. K., and Smith, F. J., July 1967. Economies of Size in Storing and Packing Potatoes--The Red River Valley Potato Industry. University of Minnesota Report No. 531, 28 pp.

ECONOMIC AND STATISTICAL ANALYSIS

Economic and Statistical Analysis Division, ERS

Problem. Frequent accurate appraisals of the economic prospects for important agricultural commodities are necessary if farmers are to plan and carry out their production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for making sound production and marketing decisions. Such information is provided through a flow of current outlook information, the development of longer range projections of the economic prospects for the principal agricultural commodities, and analyses of the economic implications of existing and proposed programs affecting major farm commodities.

Producers, processors, distributors, and consumers need information based on accurate knowledge of the interrelationships among prices, production, and consumption of farm products, and other factors. Similarly, Congress, administrators of farm programs, and analysts need such economic information to evaluate existing and alternative programs or policies in terms of their probable impact on production, consumption, and prices at both the farm and retail levels. The research program in this area provides the information for strengthening outlook and situation work.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic and applied research concerning the factors affecting prices, supply and consumption of principal agricultural commodities. The program also includes a continuous appraisal of the current and prospective economic situation of the major crop and livestock items. There are 3.5 scientist man-years devoted to research on horticultural crops in this area of which 1.5 are devoted to research on fruits and nuts and 2.0 to vegetables and potatoes.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend heavily on the USDA for across-the-board commodity situation and outlook research. However, the State extension staff members supplement and adapt such research information to meet the commodity situation of their States. The total direct research effort at State experiment stations in the situation and outlook area is approximately 10.0 scientist man-years. While not designed as outlook research, much of the research conducted by the experiment stations and reported under supply, demand and price analysis contributes to improved understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

Many of the States carry on supply, demand and price analyses for the products of their State. Much of the research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analyses methodology. A total of about 39.4 scientist man-years is devoted directly to this area of research.

A. Situation and Outlook Analysis

1. Fruits and Tree Nuts

Continuing emphasis was given to special presentations in the Fruit Situation of data on processed citrus and noncitrus fruits, geographic distribution of fruit and nut production, and per capita consumption. Revisions were made in per capita consumption series of individual and broad groups of fresh and processed fruit and tree nuts on the basis of the 1964 Census of Agriculture. Further refinements were made in some series, especially per capita data for pineapples and bananas. Compilation of historical data on foreign trade in both fresh and processed fruit has been started. An article in the July 1967 issue of the Fruit Situation examined the seasonal pattern of fresh fruit marketings on the basis of unload totals for 41 cities from 1964 through 1966. Total supplies were seasonally large during the summer and early fall harvest period for most deciduous crops, when supplies of citrus were small. Reduced marketings of noncitrus fruits during the winter were largely offset by increased supplies of citrus. Month-to-month fluctuations in total fruit deliveries were small.

2. Vegetables and Potatoes

A major report on demand and price for potatoes was published, including a review of developments in potato processing, consumption trends, and the use and impact of government programs on the production and marketing of potatoes. Another report, published by OECD in early 1967, examines trends and current status of the U.S. horticultural industry, and provides general indications for production and utilization over the next few years. A paper detailing recent market developments for horticultural commodities in North America was presented at the Fifth International Congress on Fruit and Vegetable Standardization and Marketing Methods.

Due to the interest in the marked changes occurring in the utilization and consumption of potatoes, data were developed which show per capita consumption in fresh form, and for each of the important processed potato products. Consumption of fresh tablestock has dropped a third since 1950, and now accounts for about 60 percent of the total per capita use. Consumption of frozen and dehydrated potatoes, and potato chips, has increased manyfold.

B. Supply Demand and Price Analysis

1. Citrus

Projections of production, prices, and utilization of oranges through 1970-71 were made. Prospective production over the next 5 years will increase considerably, and prices will likely be depressed. Orange exports on a fresh equivalent basis by 1970-71 were assumed to be about twice the 1965-66 levels. Fresh use of oranges will likely decline further from 17 percent of total production in 1965-66 to 13 percent in 1970-71. The use of frozen concentrates was projected to increase from 62 percent of total consumption to 70 percent over the same period.

2. Vegetables and Potatoes

Demand and Price Analysis for Potatoes was published as Technical Bulletin No. 1380. Included in the bulletin are statistical analyses of economic relationships for each of the various seasonal potato markets, and detailed discussions of the nature of demand for potatoes, consumption and price trends, the potato processing industry, and the influence of government programs. During the period studies, consumer response varied from as elastic demand for winter and early spring potatoes to a highly inelastic demand for fall crop potatoes. Changes in income appeared to have little effect on consumption; prices of competing or substitute foods also had little influence on the consumption and price of potatoes.

A study of demand relationships for selected processed vegetables is underway, with work during the past year mainly devoted to developing appropriate series of prices and supplies.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Situation and Outlook

Fruit and Tree Nuts

Blum, M. A. and Huang, B. W. Fruit Situation. Published quarterly, ERS, USDA, Washington, D.C.

Huang, B. W. July 1967. Marketings of Fresh Fruits During 1964-66. Fruit Situation, pp. 18-19.

Vegetables and Potatoes

Kuryloski, D. S. Vegetable Situation, published quarterly, ERS, USDA, Washington, D.C.

Supply, Demand and PricePotatoes

Hee, Olman, July 1967. Demand and Price Analysis for Potatoes. Tech. Bul.
No. 1380, USDA, 123 pp.

CONSUMER ATTITUDES AND PREFERENCES

Standards and Research Division, ARS

Problem. Domestic consumption of agricultural commodities depends on the behavior of some 190 million consumers. But, in our complex marketing economy, it has become almost impossible for consumers to discuss their preferences, opinions, satisfactions, and dissatisfactions with producers and marketers. Knowledge of consumer reactions to agricultural products is becoming increasingly important because we are in a period of rapid change: There is a growing challenge to farm products and farm income from a wide variety of competitive products of nonagricultural origin; there is a proliferation of mixtures, forms, processes, and other innovations affecting farm products; and that mistakes in developing, producing, and marketing farm products are costly not only to the farmer but to processors and handlers as well. An understanding of consumer reactions and the reasons behind them is essential to planning improvements in the production, marketing, and processing of agricultural products, developing educational programs, setting or revising grades or standards, evaluating new products developed by the Department's Utilization Laboratories, and identifying areas on which technical research should be focused to provide farm products in the forms and with the characteristics that will increase consumer acceptance and more closely satisfy consumer demand.

USDA AND COOPERATIVE PROGRAM

The Special Surveys Branch provides the consumer, in a scientific and unbiased manner, with an opportunity to say what he or she thinks about agricultural products by conducting applied research among representative samples of household, industrial, or institutional consumers and potential consumers. Such research may determine opinions, preferences, buying practices, knowledge and habits with respect to various agricultural commodities, the role of competitive products, and acceptance of new or improved agricultural products. The Branch also operates a sensory evaluation laboratory designed for small-group experiments in taste and visual preference and discrimination in which people's reactions to various products can be ascertained under controlled conditions. Such research applies to grades and standards problems and marketing problems as well as product development or product improvement efforts. These studies of the reactions of consumers which affect their purchase and use of farm products provide a line of communication from consumers back to those concerned with production and marketing, and are complementary to the marketing and economic research of the Economic Research Service and the Consumer and Marketing Service as well as to the utilization research of the Agricultural Research Service.

In addition, the Branch provides consultants and conducts special studies, upon request, for other agencies in the USDA or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies. The research is carried out in cooperation with other USDA or

Federal agencies, state departments of agriculture, experiment stations, land-grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are sometimes conducted by the Washington staff with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology or other social sciences, in Washington, D.C., which is headquarters for all the research whether it is conducted under contract or directly by the Branch. The Federal effort devoted to research on consumer preference of fruits and vegetables during the past year totaled 2.8 scientist man-years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

1. Citrus. A contract has been signed with a private research firm to gather information from a nationwide sample of homemakers on their experiences, beliefs, attitudes, and criticisms of citrus and citrus products, as well as the impact of synthetic products on their attitudes toward natural fruit products. Small-scale exploratory activity will be conducted prior to the main survey to assure that major issues related to attitudes toward the purchase and use of citrus fruit products that might otherwise be overlooked or distorted are covered in the full-scale survey, or at least identified for consideration. The citrus fruits currently being considered for coverage in the questionnaire are oranges, grapefruit, and lemons. The field work on the main survey is tentatively planned for either February or March of 1968.

2. Grapefruit & Orange Juice Crystals. A study is underway to evaluate consumer acceptance of foam-mat dried grapefruit juice crystals, and to provide insights into the measures which might be taken to market crystals effectively. The research is being financed in part by ARS. The test product was supplied by ARS's Fruit and Vegetable Products Laboratory, Winter Haven, Florida. The crystals are made from real grapefruit and are reconstituted into grapefruit juice by adding water.

Data were collected during May and June 1967 from a sample of private households in the Pittsburgh, Pa., area. Sweetened and unsweetened grapefruit juice crystals were alternately placed in about 200 households where the homemakers indicated that they had used grapefruit juice and 200 households where they had not used grapefruit juice in the preceding six months. A second placement - sweetened in the households where unsweetened had been placed and vice versa - was made about a week later so that each participating family had an opportunity to evaluate both versions of the product. The survey investigated areas such as: reasons for use or non-use of grapefruit juice; opinions of the advantages and disadvantages of canned and frozen

concentrate grapefruit juice; advantages and disadvantages assumed from a description of the test product; satisfactions and dissatisfactions with both types of the test product after testing it; and opinions about ease of reconstitution. Coding of the data is currently in process. Some preliminary data from this study may be released during the fall of 1967; a final report on the findings will be published in 1968.

In addition, experiments were conducted in the sensory evaluation laboratory on grapefruit juice crystals. Tests were run on the grapefruit juice crystals, a commercial canned single strength juice, and a commercial frozen concentrate; it was found that the flavor of the latter two rated higher than the flavor of the crystals. Another experiment was designed to determine which peel oil level was preferred so that it could be used in the product prepared for the household placement study.

Experiments were also conducted on orange juice crystals provided by the Winter Haven Fruit and Vegetable Products Laboratory to determine reactions to the juice when different percentages of peel oil are added. The first series of experiments, which was conducted with four peel oil levels (.015%, .020%, .025%, & .030%) indicated that higher levels might be acceptable. Therefore, a second series of experiments was conducted with three higher peel oil levels (.040%, .050%, .060%) and the .030% level from the previous tests so that the results of the two series might be compared. The results of these experiments indicate that none of the peel oil levels was too high to be preferred under sensory evaluation laboratory conditions.

3. Three fruit juices. Laboratory experiments were conducted to determine relative preference for three fruit juices--cherry, grape, and apple--reconstituted from powders manufactured by two different processes. These tests had been requested to verify the results of tests done at Michigan State University. Although the procedures used in our laboratory were different from those used at M.S.U., the results were similar and the conclusions were the same.

4. Potatoes. The coding and tabulating of data from a nation-wide study collecting information from homemakers on their use of and opinions about selected potato products have been completed, and a final report is being prepared for publication in 1968.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Clayton, L. Yvonne. 1966. Homemakers' Use of and Opinions About Selected Fruits and Fruit Products. Marketing Research Report No. 765 (S&R 3-6)

IMPROVEMENT OF CROP ESTIMATING PROCEDURES

Standards and Research Division, SRS

Problem. The Statistical Reporting Service prepares a large number of official estimates for agricultural and related enterprises. These statistics are published in the more than 700 reports issued each year. The critical need for precision estimates for the agricultural economy makes it imperative that modern statistical theory and methods be developed and incorporated into the collection and analyses of agricultural statistics. Many new techniques have been developed and introduced into the estimating procedures. However, owing to the changing structure of agriculture, the development of new technologies and the demand for more and better statistics there is an urgent need for continued research and study to devise more efficient sample survey methods to insure continued improvement in the quality of SRS statistics.

USDA AND COOPERATIVE PROGRAM

The Statistical Reporting Service conducts a program of applied research designed to strengthen and improve the methodology used in collecting agricultural statistics. The principal disciplines involved are mathematics, statistics and probability but other disciplines relating to a particular subject or field are employed as required. Examples of these subjects are plant physiology, psychology, cartography and photogrammetry. The current program consists of 6.0 professional man-years per year devoted to the study of sampling techniques and survey methods, and 4.0 professional man-years working on methods for forecasting and estimating the yields of important crops. Work under this program is done in Washington, D.C., and in SRS field offices located in the States concerned and includes the development of objective forecasting procedures for apples and potatoes.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

Apples. Studies were begun during the spring of 1967 to evaluate the efficiency of various methods of sampling limbs within trees and to explore the use of photography in limb sampling and in fruit estimation.

A sample of trees was selected in an orchard in Northern Virginia and photographs were taken in early spring while the trees were dormant. Various positions and camera-film combinations were investigated. In June these sample trees were "mapped", (all possible sample limbs were identified) and fruit on the entire tree was counted. The data from the mapped trees are being used to evaluate the efficiency of several methods of sample

limb selection. These data along with the early spring photographs are also being used to explore procedures for making sample limb selections on photography. This procedure would allow some selection methods to be used which are not practical in field sampling.

Photographs of the sample trees were taken in June after the fruit was large enough to be easily visible. Sample limbs were selected and counted. Tags of various designs and colors were placed on the counted limbs. These photographs are being used to explore the feasibility of using counts from them in conjunction with field counts in a ratio estimate of fruit on the tree. The sample trees will again be photographed when the fruit is near maturity to evaluate the effect of fruit size and maturity on its visibility. The fruit from the sample trees will be counted and weighed at harvest to determine actual production from the trees.

The extension of the same techniques to other deciduous fruit is being investigated.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

None.

